Development of Methods for Benefits Assessment of ITS Deployment in Wisconsin

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Executive Summary

The formal Intelligent Transportation Systems (ITS) program in Wisconsin has been in place since 1993. During 2000 and 2001, planning and program-level resources have been determined for a 10-year timeframe. However, as the Department moved in 2002 toward development of specific design criteria, a need was identified for more detailed benefit/cost analysis tools to enable engineers and other practitioners to make quantitative, data-based decisions comparing one type of solution to another. Wisconsin-based case studies were desired to help decide what approaches to employ to optimize use of resources to solve congestion and safety problems on the Wisconsin transportation system. This project identified the current state of the practice in ITS benefits analysis, proposed an overall structure for developing and evaluating ITS alternatives, and finally developed six ITS benefits case studies representing a range of applications and technologies.

The specific activities of this project included:

- A literature review designed to identify state of the art in ITS benefits analysis. The purpose of this task was to update previous work conducted by the University of Wisconsin-Milwaukee. These findings are summarized in Section 1.0 of the report.
- Identification of benefit/cost methodologies appropriate for use in Wisconsin and recommend a set of tools to be tested. The literature search identified three levels of tools that can be applied to the evaluation of ITS benefits:
  - A network-based tool that can utilize regional travel demand models, or other network-based data and evaluate benefits at the regional or corridor level. The ITS Deployment Analysis System (IDAS) was identified as the most advanced tool for this purpose.
  - A traffic simulation technique that can evaluate operations in greater detail on freeway and major arterial corridors. The Freeway Service Operations Analysis (FSOA) project being conducted by WisDOT District 2 will address this need.
  - A spreadsheet-based technique for use in stand-alone or limited ITS deployments, or for use in areas where travel demand models are not available.

These recommendations are also summarized in detail in Section 1.0.

- Development of a deployment philosophy for development of ITS alternatives. This philosophy is built on parameters already identified by WisDOT and covers a range of ITS solutions that can be applied in different settings across the State. This work is covered in Section 2.0 of this report.

- Identify candidate case studies that cover a range of ITS applications and geographic settings. Wisconsin DOT and Cambridge Systematics identified a set of potential case studies that could be used to demonstrate the ITS benefit methodologies discussed in Section 1.0. These studies were presented to the technical committee in a workshop format and ultimately narrowed from 13 case studies to six. These studies included:
  - Deployment of a freeway and arterial management system on the U.S. 45 corridor in Milwaukee County. The analysis included conversion of WisDOT Metamanager data to IDAS.
  - Installation of ramp meters and supporting ITS deployments on the Beltline in Madison. The analysis included conversion of the regional travel demand model network to IDAS and comparison of results with an empirical study conducted by the University of Wisconsin.
  - Deployment of an overheight detection system on U.S. 41 in the Appleton area. The analysis involved development of a spreadsheet tool to calculate benefits and costs based on historical bridge "hit" and repair cost data.
  - Improved Commercial Vehicle Operations program management including "smart scale" installations and an automated permitting system. Data were not available to develop a tool but an analysis procedure was provided.
  - Installation of an Automated Vehicle Location system for the Milwaukee County Transit System. A spreadsheet model was developed for use in conducting benefit/cost analysis on a system or route-by-route basis.
  - Deployment of an ITS system to support a major construction project on East Washington Avenue (U.S. 151) in Madison. The regional travel demand model was converted to IDAS and modified to estimate the impacts of construction and the mitigation that would be provided by the proposed ITS system.

A summary of the of the candidate case studies and selection process is included in Section 3.0. Detailed descriptions and instructions for the analysis methods are included in the appendices to the report.

The report was presented to the SPO, Bureau Director and other attendees at the Statewide Annual Planning Conference in Green Bay on June 9, 2004 as a training module.

Conclusions and recommendations are presented in Sections 2.0 and 3.0. Section 2.0 provides a framework for ITS benefits evaluation that will support efforts to "mainstream" ITS into the transportation planning process. Recommended parameters and procedures for evaluation are included. The case studies presented in Section 3.0 confirm the initial conclusion in Section 1.0 that a variety of techniques can be applied to ITS benefits evaluation, with the specific technique dependent on both the complexity of the project and the availability and quality of supporting data. Spreadsheet and network models were both tested successfully. The IDAS software was used to successfully import data from both the statewide metamanager database and the regional travel demand model for Dane County. The Freeway Service Operations Analysis project in District 2 provides another useful tool for analysis, the Paramics mircosimulation model. This model can be used independently or in association with IDAS to evaluate benefits of freeway management strategies.

It is anticipated this methodologies and tools developed for this project may form a pattern for wider B/C analysis for certain system aspects and may be utilized in conjunction with that effort.

1.0 Literature Review

Since the Federal government began its Intelligent Transportation System (ITS) deployment programs in the early 1990s, information about the costs and benefits of ITS investments has been accumulated largely through field operational test evaluations. As ITS projects are gradually being mainstreamed into the capital investment decision-making process, ITS projects must increasingly compete with traditional capital investment projects for funding. Evaluation of ITS project impacts requires cost and benefit data from existing projects and model simulation tools. In this transitional phase of integrating ITS projects into the planning process, the emphasis is no longer only on ITS field operational evaluations for deployed projects, but also on the development of methodologies for impact evaluations of proposed projects. This section presents a review of recent nationwide research efforts related to the development of potential impact evaluation methodologies as well as field operational evaluation methodologies, which often provide guidance in the design of the former.

1.1 ITS Benefits Databases

Numerous studies have been conducted to evaluate project impacts and performance, but these studies and their findings were fragmented and difficult for interested parties to access. As the development of methodologies for impact evaluations becomes increasingly necessary, the need to centralize this information has led to the development of on-line ITS benefits databases.

The most extensive on-line database on this topic is the Federal Highway Administration (FHWA) ITS Benefits Database. The FHWA database is a storehouse of ITS benefit studies and findings that have been organized to aid ITS practitioners at Federal, state, and local levels in policy analyses and benefit/cost analyses. Studies are summarized and categorized by ITS measure and by benefit measures. In cases when a study is available on the Internet, a live-link to the document is provided. The ITS JPO has made it an ongoing effort to update the database with new studies and data. The JPO also produces periodic update summary reports of ITS impact findings. The IDAS benefits library is now maintained through the updating efforts of the FHWA database.

In addition to the FHWA Benefits Database, the University of California-Berkeley's PATH program supports a web site called ITS Decision,[1] formerly named Learning from the Evaluation and Analysis of Performance (LEAP). ITS Decision was developed to provide information regarding the nature and

[1] http://www.path.berkeley.edu/itsdecision/.

performance of ITS projects. While not its principal function, ITS Decision also maintains a library of reports and articles on ITS Benefits and Costs. The ITS Decision collection, however, is not as comprehensive as that maintained by the FHWA, nor is it organized to facilitate simple queries on ITS and benefit measures.

1.2 University of Wisconsin at Milwaukee Study

Researchers at the University of Wisconsin at Milwaukee (UWM) prepared a comprehensive report[2] that discusses the framework and methodologies for the evaluation of ITS. The report provides a review of most of the prominent methods available to planners and researchers. The two major approaches to ITS benefits evaluation are the goal-oriented approach and the economic analysis approach. The goal-oriented approach sets specific objectives and evaluates a project based on its success or failure in achieving those objectives. The U.S. DOT has identified six important measures, dubbed "A Few Good Measures," for such evaluation studies. These measures include crashes, fatalities, travel time, throughput, user satisfaction/acceptance, and cost.

The economic analysis approach evaluates whether an ITS project is cost-efficient and how the rate of return on investment compares with other projects. This approach attempts to quantify short- and long-term impacts. These are similar to the benefit/cost analysis approaches discussed earlier. While the use of the goal-oriented approach is emphasized for local projects and the use of the economic analysis approach is emphasized for statewide analysis, it is critical to use a combination of both approaches to perform a fair evaluation of ITS deployment. The report also heavily stresses the coupling of the break-even analysis with any evaluation in order to gauge the reasonableness of meeting necessary performance standards.

Some of the issues to be considered in an evaluation approach are:

- The scale of the analysis (i.e., project or systemwide levels);
- The interest groups (i.e., those that may be directly or indirectly impacted);
- The timeframe for evaluation and documentation of short- and long-term impacts; and
- The measures and parameters used for project evaluation.

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[2] *A Framework for the Evaluation of the Benefits of Intelligent Transportation Systems – A Research Project Sponsored by the Wisconsin Department of Transportation*. Center for Urban Transportation Studies, University of Wisconsin-Milwaukee. December 2000.

The report recommends using benefit trees to help identify the wide range of impact categories for ITS applications. The benefit tree can be used to indicate how technology affects different stakeholders as well as the relationship between each of these stakeholder groups. Additionally, benefit trees can help to distinguish the impacts to users (internal impacts) and non-users (external impacts).

These benefit/cost approaches require a clear understanding and quantification of the costs of ITS implementation and all the benefit categories including social, economic, and safety benefits. Clearly, this poses a serious challenge to planners as they compare a variety of complex alternatives. More recently, other models and simulation tools have been or are being developed for ITS evaluation, some of which are discussed below.

The report identifies two groups of models that are available for benefit/cost evaluation. The first group encompasses add-ons to transportation planning models, such as ITS Deployment Analysis System (IDAS), Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN) and Transportation and Analysis Simulation System (TRANSIMS). The other group includes spreadsheet-based models, such as SCReening for ITS (SCRITS), which are used at the sketch-planning level.

IDAS is designed as a tool to evaluate costs and benefits over a wide range of ITS alternatives. As mentioned above, it incorporates an extensive database of technologies and national averages of field studies and modeling results. It is designed for use by regional and local planning agencies to identify projects for ITS implementation. It uses the results from the traditional four-step modeling process as the base case scenario. These results are then used as input. IDAS uses travel demand model output to estimate the incremental costs and benefits resulting from various ITS deployments. IDAS is a relatively easy-to-use modeling system and an inexpensive tool for ITS evaluation.

PRUEVIIN is an extension of the four-step planning process and is designed to assess regional- and corridor-level impacts of ITS improvements. It combines the use of regional forecasting process and simulation modeling to produce a broad range of effectiveness measures for ITS projects. PRUEVIIN includes a feedback component in which the travel models are run repeatedly until convergence, thus offering more accurate results. This model is suited for alternatives analysis at the corridor level.

TRANSIMS is being developed as a regionwide activity-based simulation model to simulate activities of individuals and households. It is capable of representing various ITS components and can be used for ITS evaluation.

SCRITS is a spreadsheet analysis tool for estimating the user benefits of ITS. It is intended to provide initial indications of possible benefits from various ITS applications. Base data such as the vehicle-miles of travel and vehicle-hours of travel are required as input. This is compared with the measures obtained when ITS is deployed. SCRITS is flexible and allows different levels of geographic analysis.

1.3 Insights from Other Studies

Beyond the UWM report, few studies have been as comprehensive in the discussion of evaluation methodologies and no other such report has been as recent. The majority of ITS benefit/cost studies have been field evaluations seeking project-specific quantitative results. Studies that address the issue of evaluation methodologies tend to provide guidelines on conducting project-specific evaluations and discuss the taxonomy of benefits and measures of effectiveness. While the objectives of most ITS studies are different than that of the UWM report, relevant issues emerge from these other discussions that enrich our understanding of how to better integrate ITS projects into the planning process.

1.3.1 Using Benefit/Cost Analysis

While the identification and quantification of benefits and costs has become the practice's standard for project evaluation, the University of California-Berkeley illustrates circumstances in which different approaches to benefit/cost analyses are pertinent. The UC-Berkeley study[3] identifies three approaches to benefit/cost analyses: the traditional benefit/cost approach, impact analysis, and cost-effectiveness analysis.

- The traditional benefit/cost analysis compares the sum of the benefits and the costs of a project at a common point in time. The project selection criteria can include: the net present value, the benefit-to-cost ratio, and the internal rate of return. These measures are typically used when performing an alternatives analysis.
- Impact analysis is a structured and comprehensive effort to identify the consequences of a specific action or policy. It involves determining what, where, and when the impacts occur. The two critical steps in this approach are the measurement of the impacts and the evaluation of their significance. The three major areas of impact analysis include the social impact analysis, environmental impact analysis, and economic impact analysis.
- Cost-effectiveness analysis seeks either to maximize the extent of achieving a goal with a predetermined budget or to achieve a specific goal at minimal cost. In this circumstance, the goals of the project are usually set without giving consideration to cost. This analysis is most often used when value is placed on human lives.

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[3] Gillen, D. and Jianling Li. *Evaluation Methodologies for ITS Applications*. California PATH Program, Institute of Transportation Studies, University of California, Berkeley. February 1999.

1.3.2 Customer Satisfaction

In the process of determining the costs and benefits of an ITS project, it is difficult to capture customer satisfaction. However, as evidenced by the ramp metering project in the Twin Cities,[4] it is clear that the issue of customer satisfaction alone can bring an ITS project to a complete halt. In his presentation of ITS evaluation and assessment,[5] Dr. Joseph Peters of the ITS JPO stated that while ITS projects have goals in safety, efficiency, mobility, productivity, and energy and the environment, he believes that customer satisfaction is the bottom line goal. In an international workshop on ITS benefits,[6] participants discussed the need for both qualitative and quantitative data in order to conduct a complete evaluation. Toward meeting that end, members of the workshop emphasized the importance of scoping studies (i.e., surveying a population to determine their transportation needs) for both project evaluation purposes and policy development.

1.3.3 Evaluating a Range of Conditions

It is important to note that network-based ITS models that are based on regional demand models typically evaluate the impacts of an ITS project on an average-day basis. This is noteworthy because it is unrealistic for an ITS project to experience only normal days throughout the course of its lifetime. An impact study conducted in Seattle[7] states that "…ITS typically has a greater impact when unusual conditions prevail, i.e., snow, special events, and major accidents… Accounting for these ITS impacts under various conditions is critical for an accurate evaluation…" IDAS overcomes this limitation to some extent by estimating benefits drawn from ITS deployments on a link basis. These benefits can be based on either national or local data. Another approach would be to evaluate the impacts as a series of short-term simulations over a longer representative timeframe, such as an average year. This would entail extensive data and analysis of that data. While much of this information is produced by the ITS systems themselves, lack of resources has limited it use for planning purposes.

1.3.4 Simulation-Based Network Design Models

As simulation-based network design models are emerging on the horizon, they are worth noting to better understand their role in the evaluation of a project. These types of models are designed to evaluate system impacts at the operational

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[4] *Twin Cities Ramp Meter Evaluation*. Cambridge Systematics, 2001.

[5] Peters, J. Presentation on *Intelligent Transportation Systems: Evaluation and Assessment*, Symposium on Weather Information for Surface Transportation. December 1999.

[6] Proceedings from International Workshop of ITS Benefits: *How Evaluation Results Are Used in Transportation Decision-Making*. Turin, Italy. November 2000.

[7] Wunderlich, K., J.A. Bunch and J.J. Larkin. *ITS Impact Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results*. September 1999.

level. That is, their strength lies in developing detailed impact evaluations of ITS applications on a corridor level and on an individual traveler level. These tools are very helpful for ITS system design refinement, but are lacking the macroscopic view necessary for conducting comprehensive impact assessments. Some of the more prominent tools include DYNASMART, MITSIMLab, VISTA, and Paramics.

DYNASMART[8] is a network analysis and evaluation tool developed at the University of Texas at Austin. It models the evolution of traffic flow that results from the decisions made by drivers on the network. It serves to support strategic and operational planning decisions by helping to identify deficiencies and to design and evaluate the impact of alternative courses of actions. One of the applications of DYNASMART is in Advanced Traffic Management System Strategies, including variable message signs location and information supply strategy, adaptive coordinated ramp metering, and incident management schemes.

MITSIMLab,[9] developed by the Massachusetts Institute of Technology, is a simulation-based tool developed for evaluating advanced traffic management systems and route guidance systems. MITSIMLab is a synthesis of different models that represent a wide range of traffic management system designs, the response of drivers to real-time traffic information and controls, and the dynamic interaction between the traffic management system and the drivers on the network. A microscopic simulation approach is used to simulate the movement of vehicles.

VISTA[10] is a mesoscopic program that is being developed at Northwestern University. It is similar in its functionality to the above mentioned tools but the advantage of this tool is its ability to run over a network on a cluster of UNIX machines, thus requiring less centralized computing power.

Paramics, developed by Quadstone, is a microsimulation tool that displays traffic flow and driver-to-driver interaction in real-time for operational and design purposes. Unlike most other simulation tools, it can provide dynamic assignment over road networks of unlimited size.[11] Paramics has been used to model the impacts of Advanced Traffic Management Systems (ATMS) such as signals and ramp meters, loop detectors linked to variable message signs and in-vehicle route guidance systems.[12]

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8 http://www.ce.utexas.edu/prof/mahmassani/DYNASMART-X/dynasmartp/home_p.html.

9 http://web.mit.edu/its/products.html.

10 http://its.civil.northwestern.edu/vista/.

11 http://www.sias.co.uk/sias/paramics/what.html.

12 http://www.its.uci.edu/its/research/its.html.

1.4 SUMMARY

The two most prominent approaches to assessing the benefits of an ITS deployment are the goal-oriented approach and the economic analysis approach. While each approach is emphasized for different coverage areas, it is important to note that these methods actually complement each other in conducting a complete evaluation. Often, the economic analysis is a component of the goal-oriented analysis.

Various ITS impact evaluation tools either have been developed or are being developed. Each tool has its own strengths and weaknesses as summarized in Table 1.1.

Table 1.1 ITS Benefit/Cost Tools Summary

Method	Description	Stage of Development	Flexibility[a]	Role in Evaluation	Data Requirements
SCRITS	Spreadsheet-based	In use	Yes	Preliminary impact evaluations – Sketch-Planning	Vehicle miles and Vehicle hours of travel
IDAS	Network-based with spreadsheet component	In use	Yes	Overall impact evaluation – Alternatives Analysis	Travel demand model and network data
PRUEVIIN	Network-based with simulation component	In use	Yes	Overall impact evaluation – Alternatives Analysis	Travel demand model and network data
Simulation Tools	Activity-, simulation-, and network-based	In use/ Testing	No	Detailed impact analysis – Project Design	Time varying travel data and network data

[a] Flexibility suggests applicability to geographic areas of different sizes.

- SCRITS, while offering flexibility in applicability to a range of geographic areas, is not a precision tool and is designed only to offer a preliminary indication of potential benefits.
- IDAS is designed as an add-on to the four-step modeling process. IDAS is flexible in its applicability to geographic areas of different sizes while its dependence on the quality of the output from regional transportation models has both positive and negative aspects. On the positive side, the analysis will provide consistency with model development work that has been ongoing in most metropolitan areas for over 30 years. On the other hand, any errors of inconsistencies in these complex models will be carried through to the ITS analysis. It is therefore important that the accuracy of the travel demand model in the geographic area of interest be noted, and adjustments made if necessary. IDAS includes cost and benefit spreadsheets that can be used independently of the network model for less complex analyses.
- PRUEVIIN uses simulation modeling and is designed as an extension to the four-step modeling process. It offers the flexibility of application to both corridor- and regional-level analysis and also has a limited feedback between the simulation and the four-step process thus allowing the models to reflect the changes in the system.

- TRANSIMS is an untested simulation tool that is designed to be used at any level of analysis but has extensive data requirements such as time-dependent demand and accurate network data.
- Simulation-Based Network Design Models such as DYNASMART, MITSIMLab, VISTA, and Paramics are a combination of traffic simulation and network assignment models. They rely heavily on good network data and travel demand estimates over time. While simulation tools are state-of-the-art, they are not widely tested and are difficult to implement. One may also argue that the strength of these models lies in conducting operational evaluations and not in project impact assessments.

In conclusion, IDAS and PRUEVIIN offer the best tools for project evaluation as they have limited data requirements and integrate well with the regional transportation modeling process. However, IDAS has a few advantages over PRUEVIIN:

- When using IDAS, deployment and simulation of various ITS components is very simple (properties and parameters can be modified directly on the maps);
- IDAS includes a large, up-to-date database that describes the costs and direct benefits of a wide variety of ITS elements;
- IDAS inputs are spreadsheet-based. These spreadsheets, with some modification, can be used independently to evaluate similar deployments. This enables consistency to be maintained between the two methods; and
- IDAS has less restrictive requirements for data.

2.0 Study Methodology and Background

2.1 Case Study Selection Overview

2.1.1 Background Issues

A number of background issues were identified that influence the selection of case studies. Key issues identified include:

- WisDOT has relied heavily on dedicated ITS funds, particularly Federally earmarked funds, for deployment of the State's ITS program. It is likely that with upcoming reauthorization of the Federal transportation program, these funds will not be as readily available. It is important that with any new funding strategies, WisDOT has the ability to evaluate the benefits and costs of ITS projects, in a manner similar to that of other projects.
- This project reflects an interest by WisDOT in "mainstreaming" ITS into the planning, design and project development processes of the Department. In order to accomplish this, a range of tools are needed to evaluate ITS projects. As with other types of transportation projects, the tools used for evaluation should be appropriate to the scale and complexity of the problem being addressed and the alternatives being proposed.
- The most extensive application of ITS technology in Wisconsin is the MONITOR system, which provides freeway management and traveler information services in the greater Milwaukee area. This system has been a major success and helped to generate interest in ITS applications in other parts of the State. However, many of the applications appropriate to smaller urban and rural areas are different than those in larger urban areas. While urban areas can support full-time ITS specialists, smaller urban and rural areas generally cannot. Therefore engineers and planners in smaller urban and rural areas require tools that can be applied quickly and with a limited background in ITS.
- The oldest portions of the MONITOR system have been in place since the early 1990s and are beginning to need replacement. WisDOT faces difficult questions regarding technology selection and operating strategies related to new technologies. Flexible tools are needed that can incorporate new technologies and new data generated by these technologies. These tools are also needed to support growing interest in asset management and investment strategies. WisDOT District 2 implemented the Freeway Service Operations Analysis (FSOA) project to develop a set of advanced tools for management of the freeway system.

In summary, new analytical tools are needed to address the changes that are influencing the deployment and operation of ITS.

2.1.2 Key Activities

The major activities of this effort include:

- A literature review designed to identify state-of-the-art in ITS benefits analysis. The purpose of this task was to update previous work conducted by the University of Wisconsin-Milwaukee. These findings are summarized in Section 1.0 of the report.
- Identification of benefit/cost methodologies appropriate for use in Wisconsin and recommend a set of tools to be tested. The literature search identified three levels of tools that can be applied to the evaluation of ITS benefits:
  - A network-based tool that can utilize regional travel demand models, or other network-based data and evaluate benefits at the regional or corridor level. The ITS Deployment Analysis System (IDAS) was identified as the most advanced tool for this purpose.
  - A traffic simulation technique that can evaluate operations in greater detail on freeway and major arterial corridors. The Freeway Service Operations Analysis (FSOA) project being conducted by WisDOT District 2 will address this need.
  - A spreadsheet-based technique for use in stand-alone or limited ITS deployments, or for use in areas where travel demand models are not available.

  These recommendations are also summarized in detail in Section 1.0.
- Development of a deployment philosophy for development of ITS alternatives. This philosophy is built on parameters already identified by WisDOT and covers a range of ITS solutions that can be applied in different settings across the State. This work is covered in Section 2.0 of this report.
- Identify candidate case studies that cover a range of ITS applications and geographic settings. Wisconsin DOT and Cambridge Systematics identified a set of potential case studies that could be used to demonstrate the ITS benefit methodologies discussed in Section 1.0. These studies were presented to the technical committee in a workshop format and ultimately narrowed from 13 case studies to six. A summary of the candidate case studies and selection process is included in Section 3.0.

2.1.3 ITS Applications

Early in the project, WisDOT and CS identified a range of applications for testing. To the extent possible, WisDOT wanted the case studies to utilize projects that had either actual or planning-level data available for measurement. Therefore, these applications focused primarily on actual or planned Wisconsin

ITS projects. In general, the project focuses on these "conventional" deployments. Included are applications, technologies, and services that have been widely deployed around the country and operational for some time. In addition, several "emerging" technologies were identified, such as the "Mayday" demonstration under deployment in neighboring Rochester, Minnesota.

Some of the applications identified included:

- Ramp metering;
- Freeway service patrols;
- Incident management systems;
- Dynamic Trailblazer/route guidance system;
- Public transportation automated vehicle location and schedule information;
- Adaptive signal control;
- Weather warning systems;
- Traveler information;
- Construction zone management;
- Commercial vehicle applications;
- Tourist/special events information and management;
- Advanced railroad grade crossing systems; and
- "Mayday"/emergency systems.

WisDOT's major ITS deployment is MONITOR, the freeway management system in the Milwaukee area. A variety of other ITS projects have either been implemented or are underway in other parts of the State, such as installation of ramp meters (Madison area), overheight vehicle detection (Appleton area), commercial vehicle weigh-in-motion (Hudson and Menominee), and Dynamic Message Signs on the I-39 corridor. A number of deployments have been identified through study efforts such as the Wisconsin Statewide ITS architecture and traveler information services and the Fox Cities ITS plan. These plans, other documents and most prominently, input from WisDOT staff were used to identify a range of potential case studies for the project.

2.2 DEPLOYMENT PHILOSOPHY

The major objective of this project is to develop and test techniques for evaluating the benefits of ITS Projects. In order to effectively accomplish this, planning-level techniques are needed to develop and define alternatives for evaluation. The market packages defined as part of the ITS architecture development process provide a guideline for the development of ITS alternatives, and assure consistency of ITS planning work with the National architecture requirements. Benefit/cost analysis, however, requires development of more specific plans and proposals for ITS deployment.

WisDOT has developed an initial set of criteria for application of ITS technologies. These criteria are similar to those used for planning physical improvements such as lane additions and intersection improvements. At this point, these criteria provide a good starting point for determining whether ITS technologies can help to address a system problem or deficiency. As these methods are applied over time, and ITS system data are collected and analyzed, these criteria can be adjusted. Traffic volumes, projected congestion, and safety are key variables in identifying and evaluating ITS systems. Proximity to the existing ITS system is another important variable that will primarily impact the cost side of the evaluation. These parameters are shown in Tables 2.1 and 2.2.

One of the major purposes of the benefits analysis is to identify the optimal level of investment in ITS. The level and nature of ITS investment will differ based on several variables, including traffic volumes, accident rates, economic impacts, and congestion levels.

The concept of *deployment intensity* is the method used to address these needs. High-intensity deployments generally provide full coverage of a specific facility or geographic area. Low-intensity deployments can be viewed as both a way to provide ITS coverage in areas of lesser need where only limited investment is justified, and as a first step toward higher intensity deployment.

As ITS is deployed in outlying portions of the State, control and management strategies must also be reconsidered. In the Milwaukee region and District 2, coordination with the MONITOR system and the Gary-Chicago-Milwaukee corridor is a critical issue. As deployments move out into other areas of the State, WisDOT must determine whether satellite, or smaller traffic management centers are needed, or whether operations can be incorporated into Regional offices or even in county or municipal traffic management centers. An important consideration in these decisions is coordination between freeway management systems, which are State-operated, and arterial management systems, many of which are be locally operated.

The sections below define the concepts of high and low intensity for a range of technologies that WisDOT may consider for implementation. Included first are *core deployments*, which are those most directly related to WisDOT functions. Individual technologies are sorted into several categories including:

- Freeway Traffic Management;
- Arterial Traffic Management;
- Portable Traffic Management; and
- Advanced Traveler Information systems.

Following are listings of *additional deployments*, which include technologies that are primarily the responsibility of county agencies, local agencies or the private sector. These include ITS technologies related to public transportation, emergency vehicles and in-vehicle technologies related to safety.

Table 2.1 WisDOT Urban Freeway Environment Matrix

Urban

Urban Freeway Problems	Tiers	Threshold	Solutions***		
Present Condition			Detect	Response	Enforcement
Unplanned Incidents (Crashes, Breakdowns)	Tier #3 [least intensive]	LOS 5.0-5.5 =LOS E [Lo] Crash Hot Spot =X/mi Number of Crashes/mi= >25 and <50	Cell 911 [CAD/AVL]	TV/Radio	Enforcement
	Tier #2	LOS 5.5-6.0=LOS E [Hi] Crash Hot Spots Y/mi Number of Crashes/mi=>50 and <75	Cell 911 [CAD/AVL] CCTV*	TV/Radio.Internet; HAR [Port. Or Perm.]; CMS	Enforcement; Enhanced Enforcement ;Emergency Service [CAD/AVL & Communications]
	Tier #1 [most intensive/severe]	LOS 6.0 =LOS E/F Crash Hot Spot Z/mi Number of Crashes >75	Cell 911 [CAD/AVL] CCTV* Detectors *	TV/Radio.Internet; HAR [Port. Or Perm.]; CMS; Perm. VMS*; Alt. Route Signing*; Integrated Traffic Signals*	Enforcement;; Enhanced Enforcement ; Emergency Service [CAD/AVL & Communications] Freeway Patrols *
		Threshold	Solutions		
Special Events	Tier #3	LOS D & Major Event Days = 5	Port. CMS &/or Port. HAR		
Major Event =20,000 Attendees or More /Day	Tier #2	LOS D & Major Event Days = 15	Port. CMS/ Port. HAR &/or Perm. VMS & Perm. HAR ; Perm. Alt. Route Signing		
	Tier #1	LOS D & Major Event Days = 30	Port.CMS & Port. HAR &/or Perm.VMS & Perm. HAR; Perm. Alt. Route Signing ; CCTV; TMC*		
Construction/Work Zone Mitigation Consider Project Duration and TMC Warrants	Tier #3	Any Construction Project with current LOS D	Port. CMS & Port HAR		
	Tier #2	Any Construction Project with current LOS E and 1 Lane Closing	Port. CMS & Port HAR ; Enforcement/Service Patrols* ;Ramp Metering*		
	Tier #1	Any Construction Project with current LOS F and 1 Lane Closing	Port. CMS & Port. HAR; Enforcement/Service Patrols*; Ramp Metering; Alt. Route Signing * Coordinated Signal Systems *		
Seasonal Congestion Holiday, Weekend, and Recreational Times	Tier #3	LOS D & Holiday/Weekend	Pre-Trip Info [Web, TV, Radio]		
	Tier #2	LOS E & Holiday/Weekend	Pre-Trip Info [Web, TV, Radio]; Port. CMS & Port. HAR		
	Tier #1	LOS F & Holiday/Weekend	Pre-Trip Info [Web, TV, Radio]; Port. CMS & Port. HAR or Perm. VMS & Per. HAR; TMC*; Kiosks		
Capacity Deficiencies	Tier #3	LOS D	Ramp Metering*		
	Tier #2	LOS E	Internet/Radio/TV; Ramp Metering* ; System Detection*		
	Tier #1	LOS F	Internet/Radio/TV ; Ramp Metering*; System Detection* ; VMS*; Integrated Signal Systems ; TMC*		
Weather Events using GPS/AVL Plows & Internet Info	Tier #3	Any Storm on All Highways	Radio/TV/ Internet/ RWIS		
	Tier #2	LOS E or less	Radio/TV/Internet/Enhanced RWIS		
	Tier #1	LOS F or less on any segment	Radio/TV/Internet/Enhanced RWIS		

Traffic Operations Center [TOC]	Pop. > 500,000	many workstations or laptops linked together
Mini Traffic Management Center [TMC]	Pop. > 200,000	2 linked work stations or laptops
Mini-Mini TMC	Pop.> 100,000	1 single work station or laptop

***Matrix ITS solutions were derived from the ITS Elements list used by the Expert Panel to address the critical problems.

Source: Wisconsin DOT.

Table 2.2 WisDOT Corridor Freeway Environment Matrix

Corridor

Corridor Freeway Problems			
Present Condition	Tiers	Threshold	Solutions***
Unplanned Incidents (Crashes, Breakdowns)	**All Tiers**	S=Crash Rate & Severity All Highways C= LOS D [Rural] "Hot Spots"= Crash Rates & Severity	Cell 911 [CAD*]; Ongoing Support; Emergency Communications Systems [CMS*, CAD/AVL*, HAR*]
2 Thresholds: Safety[S] and Congestion [C]		"Hot Spot" defined as high crash numbers, high severity indices, and minimum LOS D indicators	
Special Events	**All Tiers**	Single Major Event	Portable CMS & Portable HAR
Rural--ex. Farm Progress Days, Birkenbeiner, EAA		the District's Discretion--need specific justification from District for special event	All events and all event routes; costs paid by event organizer
Construction/Work Zone Mitigation	**Tier #3**	Any Construction Project	Portable CMS & Portable HAR
	Tier #2	Any Construction Project with 1 Lane Closing	Project-Funded Enhanced Enforcement
	Tier 1	Any Construction Project with current LOS F and 1 Lane Closing	Port. CMS & Port. HAR; Enforcement/Service Patrols*; Ramp Metering* ; Alt. Route Signing *; Coordinated Signal Systems *
Seasonal Congestion	**Tier #3**	LOS D	Pre-Trip Traveler Info [Internet/Radio/TV]; Portable CMS & Portable HAR
Holiday, Weekend, and Recreational Times	**Tier #2**	LOS E [e.g. Wisconsin Dells and a communication system exists]	Permanent VMS; HAR; TMC*; & Kiosks [if needed, based on frequency, severity, and TMC Warrants; where communications exist e.g. Fibre Optic Cable provide Detector-based Traveler Information]
	Tier 1	LOS F & Holiday/Weekend	Pre-Trip Info [Web, TV, Radio]; Port. CMS & Port. HAR or Perm. VMS & Per. HAR; TMC*; Kiosks
Capacity Deficiencies	**Tier #3**	LOS D	Ramp Metering*
same as *Urban*	**Tier #2**	LOS E	Ramp Metering* must be connected to System Detection* ; Internet/Radio/TV
	Tier #1	LOS F	Ramp Metering* must be connected to System Detection* Internet/Radio/TV; VMS*; Integrated Signal Systems; TMC*
Urban Arterials	**All Tiers**	Urban routes "relieving" the freeway system or filling the gaps between freeways	Adaptive Signal Control Coordination
Weather Events	**Tier #3**	Any Storm on All Highways	Radio/TV/ Internet/ RWIS
using GPS/AVL Plows & Internet Info	**Tier #2**	LOS E or less	Radio/TV/Internet/ Enhanced RWIS
	Tier #1	LOS F or less on any segment	Radio/TV/Internet/ Enhanced RWIS

Note: It is recognized that Projects are scheduled in the six-year program. From a traffic impact standpoint, these thresholds can be advanced for the forecasted LOS to allow installation of ITS Plumbing.
***Matrix ITS solutions were derived from the ITS Elements list used by the Expert Panel to address the critical problems.

Source: Wisconsin DOT.

2.2.1 Core Deployments

Core deployments represent the basic ITS services that are monitored or managed under the current WisDOT ITS system. These generally include proven technologies that have been in operation for some time. The amount of deployment, level of monitoring, and the specific services provided on a given portion of the transportation system depend on whether it is slated for high-intensity or low-intensity deployment.

Freeway Traffic Management

The core grouping of freeway traffic management provides the basic monitoring, traveler assistance, and information feedback mechanisms for highway infrastructure. Together with arterial traffic management, freeway management functions provide the information skeleton, on which additional services depend and build.

Function	High-Intensity Deployment	Low-Intensity Deployment
Detection	100% roadway coverage (Loop Detector, Microwave, Radar, or Imaging technology). • At least one detector on each segment and ramp, plus additional detectors for long segments.	Majority coverage (Loop Detector, Microwave, Radar, or Imaging Technology). • Detector on each segment.
Surveillance/ Verification	100% roadway coverage (Streaming CCTV camera able to view entire mileage). • Fixed cameras at priority locations; pan/tilt cameras at non-priority locations. • Pan/tilt camera coverage of all interchanges.	Priority coverage. • All major interchanges and other priority locations have pan/tilt camera coverage.
Ramp Metering	Fully deployed on a corridor or systemwide basis.	Deployed at key interchanges as needed to help freeway traffic flow.
Reference/ Ramp Marker	• 0.1-mile markers. • All ramps have marker.	• 0.2-mile markers. • All ramps have marker.
Freeway Service Patrol	Dedicated service to specific routes during peak periods.	Not deployed.
Highway Advisory Radio (HAR)	• Full coverage on corridor basis. • 100% reception coverage. • Announcement signs upon entering or leaving low-intensity coverage area. • Will include road weather information too where available.	Not employed.
Dynamic Message Signs (DMS)	• Approaching every interchange, at critical decision-making locations. • On both surface road approaches to interchange (allowing sufficient time to change route).	• Approaching major interchanges. • Surface street approaches as needed.

Arterial Traffic Management

Arterial traffic management caters to the unique needs of high-volume surface streets. In these instances, the need for surveillance and service patrols is lower than that for freeway traffic management. On the other hand, deployments must address additional delay and safety concerns, resulting from the presence of signalized intersections and railroad grade crossings. Implementation of formalized incident management strategies require that excess traffic resulting from freeway incidents or construction information be accommodated. Information must be provided to both agency personnel and the public on arterial conditions, and where possible, signal timing be adaptable to major change in traffic flow.

Function	High-Intensity Deployment	Low-Intensity Deployment
Traffic Signal Coordination	Full signal coordination on all corridors identified as high-intensity, with "the bells and whistles" that go with it (actuation, coordination, control, traffic signal TMC, adaptation).	Traffic actuated signals isolated on an as-needed basis; maybe connected to TMC if needed for status determination purposes.
Surveillance/ Verification	CCTV deployed on an as-needed basis at major locations, including: • High-accident, delay, or strategically important intersections, segments, or railroad grade crossings. • Key decision point for freeway/arterial incident management strategies. • Can be pan/tilt/zoom or slow-scan fixed cameras. • Can be combined with detection (in case of camera detection).	• No CCTV deployed except when needed to monitor isolated high-accident/ traffic locations. • Tie existing detection data to Traffic Management Center at specific locations.
Signal Preemption for Emergency Vehicles	Deployed on an as needed basis, mainly in and around intersections/corridors such as: • Intersections with high emergency vehicle traffic (around hospitals, fire, and police stations). • Densely developed areas (like central business districts). • Low-capacity/long signal phasing/high-accident intersections (typically single-lane approaches).	Generally, no signal preemption. However, individual intersections or corridors may be equipped on an as needed basis, using the high-intensity criteria.
Rail Road Crossings	All railroad grade crossings on major arterials have advanced deployments, consisting of: • Cross-bucks and flashing lights; • Quad-gates and incursion detection systems; and • Railroad signal preemption. At locations where major backups occur regularly and alternate routes are available: • DMS advanced warning/real-time rerouting, and at-location status updates; and • Speed-based gate timing.	All rail grade crossings have standard deployments consisting of: • Cross-bucks and flashing lights. Advanced deployments (listed under high-intensity) should be considered on an as needed basis for high rail traffic, accident, or delay locations.

Portable Traffic Management

Elements of a portable traffic management system work in tandem with both the freeway and arterial traffic management functions to cover activities likely to cause non-recurring congestion, such as roadway construction, major events, or interim traffic management. These functions extend the reach of the basic freeway and arterial management programs by giving the system the potential to temporarily increase the level of coverage on sections of the roadway network, without investing in permanent ITS infrastructure.

Function	High-Intensity Deployment	Low-Intensity Deployment
Portable Detection	Portable detection and information equipment at construction sites along freeways and major trunklines, including: • Portable dynamic message signs; and • Detection equipment approaching and within the impacted zone.	Portable message signs with remote connection to TMC providing advanced warning of activity. Depending on length of impacted roadway and duration of activity, portable detectors may be installed to track impact.
Portable Dynamic Message Signs	Direct wireless communication between field equipment and TMC. Wireless communication between detectors and message signs with pre programmed advance information.	

Advanced Traveler Information

Provision of advanced traveler information may be a function of the public sector or may be accomplished through public/private partnerships. Increasingly cooperation is needed between public agencies that collect traffic information, and private entities that disseminate that information. Decisions regarding high- and low-intensity deployment require assumptions about what services a private provider would be willing to offer, policies that a public agency could use to encourage particular service, and actions that a public agency should take to support full information provision.

Function	High-Intensity Deployment	Low-Intensity Deployment
Cellular Phones, Pagers, Handheld Device	• Complete broadcast coverage. • Complete interactive, route-planning capabilities.	• Partial broadcast coverage. • Complete interactive, route-planning capabilities, within coverage. – Emphasis on real-time regional route choice information (for long-distance/intercity travelers).

Function	High-Intensity Deployment	Low-Intensity Deployment
Internet	Network Coverage for all portions of system where information is available. • Route-planning services for metropolitan areas focused more on disaggregated/ localized information. • Availability of real-time TMC camera feeds and speed data.	Network Coverage concentrated on major routes. • Route-planning services for outlying areas focused on regional information.
Kiosks • Multimodal and transit only • Broadcast (static TV screens and terminals) and interactive	Linked to TMC or other sources of transportation information. Deployed at high pedestrian traffic facilities, on an as needed basis including major multimodal terminals (airports, park-and-ride lots, rail stations, transit transfer points) and major commercial centers (office complexes, shopping centers, universities, public parking garages).	Displays static information on construction activity and/or transit routes. Deployed at similar locations to high-intensity, but at fewer locations.
511 dial in travel information service	Complete Coverage.	Coverage confined to major, high-intensity routes.

Incident Management – Freeway/Arterial Integration

Functions in this grouping are used to implement a defined incident management plan, to respond to major accidents or natural disasters. These functions help the designated relief arterials to accommodate increased traffic that has been rerouted off of impacted freeway segments. In high-intensity applications, active management of both freeway and arterial corridors is provided. In low-intensity applications information is provided but proactive management of the arterial system is not.

Function	High-Intensity Deployment	Low-Intensity Deployment
Incident Freeway-Arterial Signal Coordination	For freeway-alternate arterial pairs identified in a regional incident management plan. • Arterial signals along alternate corridor able to adjust for shifting traffic pattern. • Can be either manual control between freeway TMC and signal coordination center, or seamless sensor-automated control.	For freeway-alternate arterial pairs identified in a regional incident management plan. • Information provided on freeway through DMS. • Traffic monitored on parallel arterials but no proactive management.
Alternate Route Guidance (Trailblazer)	“Trailblazer” or similar dynamic route guidance signs deployed at all potential decision points along alternate arterial corridor.	“Trailblazer” signs not deployed but portable dynamic message signs may be used in certain situations.

Advanced Infrastructure-Based Warning and Safety

These include additional deployments that are generally deployed on an as needed basis at or in advance of roadway locations where potential safety hazards exist. They consist of detection, surveillance, and/or information display systems that are deployed on the roadway or roadside. Based upon the characteristics of individual vehicles detected (for example, vehicles classification, vehicle speed), these systems trigger warning messages about potential safety hazards. These are different from advanced in-vehicle systems, in that, they are deployed on the roadway or roadside, and they are monitored and controlled by public agencies. These systems may be deployed in isolated areas where the core ITS infrastructure deployment is not very intensive, or may be deployed to supplement the core deployments. Since these are limited deployments tied to a single location, there is no explicit difference identified between high-intensity and low-intensity deployments.

Function	Deployment Criteria and Assumptions
Ramp rollover detection and warning systems. These are used to detect the speeds of vehicles exiting onto a ramp based on which they display advance warnings to prevent potential rollover. These apply generally to large trucks and trailers.	• Deployed at specific ramps which meet the following criteria: – Ramps that have a high rollover accident history; – Ramps that are geometrically constrained enough to warrant such a system (recommended exit speeds are fairly low); and – Stakeholder identified safety hazard at that ramp location. • Deployed at all ramp locations that are identified as "safety hotspots."
Overheight detection and warning systems consist of radar detectors that identify overheight vehicles approaching bridges. Electronic message signs are triggered that provide warnings and directions to exit the road.	• Deployed on approach segments to overpasses that experience frequent "hits" from overheight vehicles.
Downhill speed detection and warning systems are similar to ramp rollover systems, but they apply to roadway sections where the vertical gradient can prove to be potentially hazardous.	• Deployed at specific locations where there is a downhill gradient, and where there are documented or observed safety hazards.
Advanced curve warning systems are again similar to ramp rollover systems, but they are used to warn motorists in advanced of hazardous curves based on real-time detection.	• Deployed at specific locations where there is a hazardous curve, and where there are documented or observed safety hazards. • Deployed at all roadway locations that are identified as "safety hotspots."

Commercial Vehicle Operations Support

There have been a number of initiatives at the Federal and state levels to apply ITS technology to improve the mobility, safety, and economic efficiency of commercial vehicles. Effective use of ITS technologies can improve the safety of traveling public while enabling commercial vehicle operators to avoid costly delays and paperwork. WisDOT has several active initiatives in this area under the CVISN (Commercial Vehicle Information Systems and Networks) umbrella. CVISN facilitates the exchange of motor carrier information among state, commercial vehicle operators, regional clearinghouses, and national databases.

Function	Deployment Criteria and Assumptions
CVISN systems incorporate the software and databases required to implement the program.	• CVISN systems allow carriers to apply for and receive their essential operating credentials remotely, and provides regulatory agencies with safety and inspection data.
Electronic screening systems.	• E-screening systems are deployed at weigh stations to ensure trucks are in compliance with safety and regulatory requirements. Systems such as Pre-Pass and NORPASS allow participating vehicles with transponders to bypass weigh stations. Pre-cleared vehicles proceed at highway speed, improving safety and efficiency while allowing law enforcement to focus resources on noncompliant motor carriers.
Automated commercial vehicle permitting applications.	• State DOT's are increasingly making use of the Internet to improve the convenience of obtaining overheight and oversize permits. These systems can improve customer convenience and over time, will reduce agency operating costs. Most DOT's are linking these systems with their statewide road and bridge databases, such as WisDOT metamanager, in order to reduce the labor required in researching the proposed routes.
Commercial vehicle traveler information services.	• Several demonstration projects are underway that match real-time en route information with motor carrier routing and dispatching decisions. These services will enable carriers to avoid congested areas and major incidents. • Special information systems using in-vehicle navigation systems, HAR and DMS may be utilized in specific areas with large volumes of commercial traffic such as ports or industrial areas.

Weather and Road Condition Monitoring/Management

Road condition monitoring and management functions help traffic managers detect potential weather-related problems and take appropriate measures to minimize the risks to travelers. These functions can be most useful on isolated roadway segments (where weather conditions are not reported as intensively, and response time and cost is greater), or segments with a history of weather-related accidents.

Function	High-Intensity Deployment	Low-Intensity Deployment
Roadway Condition Monitoring	Selected segments to be equipped with weather monitoring/forecasting deployments. • Regular spacing in isolated areas. • Targeted monitors for segments with a history of weather-related accidents.	Selected segments to be equipped with weather monitoring/forecasting deployments. • Targeted monitors only for locations with a history of weather-related accidents.
Motorist Warning Systems	Selected facilities/segments equipped with DMS and/or Variable Speed Limit Signs to warn motorists of dangerous pavement conditions.	Static warning signs or portable DMS used to warn motorists.
Centrally Controlled Road Closure Gates and Alternate Route Guidance	Remotely controlled barriers can close major ramps on selected isolated roadway segments. Accompanying DMSs provide alternate route instructions.	• Public safety officials notified through TMC when closure is warranted.

2.2.2 Additional Deployments

These additional deployments include services and technologies that are generally provided by county agencies, local agencies or the private sector. The intensity of some of the additional deployments (such as advanced transit management and in-vehicle systems) is dependent on the level of deployment in vehicles. Thus, it is possible to have a segment of roadway with high-intensity infrastructure deployment, but low-intensity deployment in vehicles.

Advanced Transit Management

Advanced transit management functions take advantage of electronic systems deployed on transit vehicles, at transit stops, or along transit routes. These deployments serve a variety of functions, including: enhancing passenger safety, improving information and convenience to transit riders, improving speed and reliability, and reducing cost to the transit operator.

Function	High-Intensity Deployment	Low-Intensity Deployment
Electronic Fare Payment	Fare card and readers deployed throughout system, can be connected to park-and-ride payment system, or used to pay for other goods and services (Smart card).	Fare card and readers deployed throughout system.
Automatic Vehicle Location	All transit vehicles equipped with AVL. Vehicle locations monitored by central transit monitoring center. Communication links provided so that data can be used for traffic management system.	AVL used only on most heavily traveled routes or in largest divisions. Vehicle locations monitored by central transit monitoring center.
Transit Safety Systems	All transit vehicles equipped with incident monitors. Incidents detected by central transit monitoring center.	Incident monitors provided on new transit vehicles, or vehicles serving specific routes. Incidents detected by central transit monitoring center.
Advanced Routing for Demand Responsive Transit	Para-transit routing controlled in real-time by central AVL enhanced dispatching. Communication links provided so that data can be used for traffic management system.	Para-transit routing controlled in real-time by central AVL enhanced dispatching. May be limited to certain routes and services.
Advanced Transit Vehicle Monitoring/ Maintenance	All transit vehicles equipped with vehicle status/driver condition monitors. Vehicle status monitored by central transit monitoring center.	Vehicle status/driver condition monitors limited to certain routes and services. Vehicle status monitored by central transit monitoring center.
Enhanced Transit Information	Real-time vehicle location and time to arrival provided both at stops and in-vehicle.	Real-time vehicle location and time to arrival provided at a limited number of high-volume stops.
Transit Signal Priority	Intersections and corridors along transit network equipped with transit prioritization sensors. All transit vehicles equipped with emitters.	Signal priority not deployed or limited to a few major corridors or intersections.

Emergency/Service Vehicle Dynamic Routing

Functions in this grouping take advantage of automatic vehicle location equipment and the availability of real-time traffic information to improve the dispatching – and hence arrival time, utilization, and level of service – of service and emergency vehicles. Since this technology would be applied to all vehicles in a fleet, or division, there is no distinction made between high-intensity and low-intensity deployment.

Function	Deployment
Emergency and service vehicle AVL.	All emergency and service vehicles equipped with Automatic Vehicle Location devices.
Computer aided real-time dispatch.	Vehicle location and status monitored to provide optimum real-time dispatching.

Parking Management Systems

In areas with pronounced peaks in demand for parking such as central business districts, park-and-ride facilities, universities, major medical centers and sporting and entertainment venues ITS technologies can provide information on parking cost and availability. The downtown areas of Madison and Milwaukee, as well as other areas containing major university and hospital complexes would be primary candidates for these systems. Functions in this group help reduce congestion and delay associated with finding or paying for a parking space. It is anticipated that these systems will be implemented primarily through local authorities, institutions, and the private sector.

Function	High-Intensity Deployment	Low-Intensity Deployment
Parking Garage Status Monitoring	All participating garages equipped with occupancy sensors/vehicle counters to determine number and location of available spaces.	Participating garages keep track of parking occupancy through sensors or other means and report to local control center.
Regional Parking Availability Information	Real-time information on parking status provided through varying channels: • To dedicated parking management DMSs at major local decision points; • Over Internet for pre-trip planning purposes; and • To in-vehicle information systems (if available).	Information provided regarding parking availability is static or based on historic data through means similar to those in high-intensity deployment. Information delivery mechanisms similar to those used in high-intensity deployment.
Automated Payment	All participating garages equipped with electronic payment tag readers. • Optional service for equipped vehicles.	Same as high-intensity deployment.

Supplementary Traffic Management

Supplementary traffic management functions enhance basic traffic management operations in two ways:

1. They utilize specially equipped "probe vehicles" that measure the actual conditions in the traffic stream to expand the amount and detail of available information; and
2. They allow field personnel to have greater control over the overall system in order to respond to situations more rapidly.

These deployments would be considered high-intensity if they are implemented. There is no low-intensity option presented, although there could be variation in the level of coverage.

Function	Deployment
Probe Vehicle Traffic Monitoring	AVL-equipped transit and service vehicles used to monitor flow speeds on the traffic network.
"Virtual TMCs"	All mobile service vehicles able to monitor system conditions, and control roadway management deployments such as DMSs, HAR. Monitoring and control functions are similar to that of the central TMC.

Environmental Monitoring/Management

Functions in this group are used to help municipalities facing episodic pollution problems to better manage a variety of programs aimed at reducing auto-related emissions. These deployments are particularly useful in National Ambient Air Quality Standards (NAAQS) non-attainment areas, where communities are required to implement pollution reduction programs.

Function	High-Intensity Deployment	Low-Intensity Deployment
Roadside Emissions Monitoring Stations	Specific high-traffic locations are deployed with instruments to detect real-time emissions levels. This information can be used to: • Issue areawide pollution warnings or health alerts; • Manage pollution reduction programs (such as "no-zone" days); and • Detect emissions levels of individual vehicles, and issue citations for vehicle non-compliance (advanced deployment).	Specific high-traffic locations are deployed with instruments to detect real-time emissions levels. Data collected for analysis and policy development, not real-time transportation management.

Advanced In-Vehicle Technology

The advanced in-vehicle technology grouping takes advantage of assumed private-sector improvements in the passenger vehicle fleet over the project-planning horizon. While many technologies that enhance vehicle safety and functionality already exist in prototype form, modeling the impact of these technologies requires assumptions about the degree of market penetration into the overall passenger fleet. The deployment and market penetration of these advanced in-vehicle technologies is largely beyond the control of public agencies. However, they can incorporate provisions in their long-term plan to advocate implementation of suitable systems, particularly those related to public safety.

Function	Deployment
• In-vehicle traveler information devices. (In the long term, in-vehicles information may begin to phase-out traditional road-side information systems such as DMSs or road signs.) • In-vehicle safety warnings to detect hazardous roadway/ pavement conditions. • Enhanced driver vision to enhance the driver's view of the roadway, or potential obstacles. • Driver condition monitoring to detect the driver's ability to operate the vehicle safely. • Collision avoidance systems to prevent longitudinal, lateral, and roadway departure collisions. • In-vehicle mayday systems that either deploy automatically in case of an accident, or can be used to automatically notify public safety or emergency response agencies at the push of a button.	• Information collected by the public sector for traffic management can help support in-vehicle travel information services provided by private firms. • Mayday system connection to public safety and transportation agencies can help to expedite response.

2.3 ITS Benefits Measures

2.3.1 Stakeholder Input

WisDOT formed a technical committee at the outset of the project to provide overall guidance to the effort and to help identify specific case studies that could be used in the project. An initial kickoff meeting was held in May 2002 to review the workplan and discuss the concerns of the stakeholders. Based on stakeholder input and review of WisDOT ITS program documents, CS identified a set of potential case studies for the project. In order to establish criteria for the project, a questionnaire was prepared and sent to approximately 30 to 35 stakeholders. In addition to WisDOT central office and district personnel, a sample of municipal officials and private stakeholders were contacted. Eleven questionnaires were returned including two from private transportation organizations, three from WisDOT Central Office, one from State Patrol, three from WisDOT Districts and two from local agencies.

While not all of the respondents agreed with these findings, some of the more common themes in the comments received were:

- Congestion is a major problem in the transportation system. It is spreading from the Milwaukee region and is now found more frequently in smaller urban areas and in tourist areas during peak season.
- Respondents feel that many of the safety problems experienced in the State are related to congestion. Weather, high speeds on rural highways, increased development along state highways and lenient drunk driving policies were also cited as factors in safety problems.
- Financial concerns were cited by a number of respondents who felt that funding levels are not adequate to maintain the system and provide necessary improvements.
- Several respondents noted air and noise pollution as major issues, but most did not.
- A number of respondents indicated that unlimited access to the highway system has contributed to congestion and safety problems. Several respondents noted the need for mobility among residents who do not have automobiles available.

Respondents were asked to rate the helpfulness of various types of information that can be obtained through ITS technologies. Items were rated on a scale from 1 (not helpful) to 10 (most helpful). The rankings shown in Table 2.3 indicate a strong interest in real-time traffic information, particularly information related to impact of incidents and construction activity. These rankings confirm the importance of congestion and safety issues to the respondents.

Table 2.3 Helpfulness of Information in Conducting Mission

	Average	Median
Notification of roadway incidents	8.1	9.0
Recommended detour routes for construction or incidents	7.5	8.0
Construction-related information	7.3	8.0
Real-time general traffic information	7.1	8.0
Traffic volume data	7.0	7.5
Weather-related road condition information	6.9	8.0
Camera feeds	6.3	5.5
Fleet/emergency vehicle status	5.9	7.0
Fleet/emergency vehicle location information	5.7	7.0
Operating status of signal/traffic control devices	5.3	6.0
Travel time information	5.1	5.0
Real-time personalized (route-specific) traffic information	4.8	5.0
Transit vehicle location information	3.9	3.0

Respondents were also asked to identify the benefits of the ITS-related information shown above in meeting their organization's objectives. The results obtained from the respondents on this question are compatible with the general comments provided and are shown in Table 2.4. Most respondents believe that improved information will be most useful for addressing congestion and safety issues in Wisconsin. There is interest in providing information directly to motorists and using information to more proactively manage the transportation system.

Table 2.4 Benefits of ITS Information in Meeting Objectives

	Average	Median
Better manage traffic for special events	8.1	8.0
Provide traffic-related information to motorist en route	7.9	8.5
Improve efficiency of law enforcement	7.9	9.0
Better manage construction projects	7.2	8.0
Reduce accidents	7.2	8.0
Increase speeds and reduce stops	7.1	7.0
Improve motorist safety	7.1	8.0
Provide quicker and safer response to incidents	7.0	8.5
Provide faster notification of incidents to motorists	6.8	7.5
Reduce congestion and specific places and times	6.6	8.0
Provide traffic-related information to motorist prior to their trip	6.6	7.0
Provide for safer, more efficient movement of freight	6.4	7.0
Reduce agency operating costs	6.1	7.0
Provide traffic-related information to motorists	6.0	6.0
Reduce operating and maintenance costs of transportation system	5.8	7.0
Reduce operating costs to motorists and transit users	5.4	5.0
Improve vehicle and personal security	5.3	5.0
Reduce air and noise pollution	5.0	5.0
Increase transit ridership	4.9	5.0
Reduce auto impact on neighborhood streets	4.2	4.0
Reduce overall vehicle miles of travel	3.9	3.0
Increase private vehicle auto occupancy and transit usage	3.8	3.0

The final item on the questionnaire asked whether respondents would have interest in operating or utilizing specific ITS services. The answers again indicated a strong interest in information about traffic congestion, incidents, and general travel conditions. Services that provide this information to both the general public and agency personnel had a high level of interest across all respondents. More specialized categories related to transit, commercial vehicle operations and emergency vehicle management generated a high level of interest among a smaller group of respondents.

2.3.2 ITS Benefit Measures

The results of the stakeholder survey and workshops indicate that benefits related to travel time and safety would have the highest weight in evaluating ITS projects. However, it is important to note that in specific geographic areas and in addressing certain facilities and problems, benefits related to environmental impacts, commercial vehicle operation or transit may take priority. This is why the proposed analysis tools must be flexible and must address a full range of benefits.

The benefit calculations in IDAS are based on "national" default values that have been compiled in a database maintained by FHWA's Office of Operations. The benefits portion of the database can be found at http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ByLink/BenefitsHome. Benefits are calculated based on two categories of information, performance measures and benefits valuation. The latter assigns monetary values to various benefit categories.

In applying benefit assumptions to the case studies, a set of initial values were proposed for application. These included both the national defaults, and other default values identified through IDAS projects conducted in other States. As actual studies are identified in Wisconsin further adjustments are made. The additional set of benefit parameters proposed is shown in Table 2.5.

The performance measures include the following:

- Vehicle miles of travel (VMT);
- Vehicle hours of travel (VHT);
- Average speed;
- Person hours of travel (PHT);
- Number of person trips;
- Number of accidents:
  - Fatality,
  - Injury, and
  - Property damage only;
- Travel Time Reliability (hours of unexpected delay);
- Fuel Consumption (gallons); and
- Emissions:
  - Hydrocarbon and reactive organic gases,
  - Carbon monoxide,

- Nitrous oxides, and
- PM_{10}.

The benefits valuation process applies values to the measures above to calculate:

- Annual Benefits:
  - Change in user mobility;
  - Change in user travel time (in-vehicle, out-of-vehicle, and travel time reliability);
  - Change in costs paid by users (fuel costs, non-fuel operating costs, and accident costs – internal only);
  - Change in external costs (accident costs – external only, HC/ROG, NO_x, CO, PM_{10}, CO_2, global warming, noise, other mileage-based external costs, and other trip-based external costs);
  - Change in public agencies costs (efficiency included);
  - Other calculated benefits; and
  - User-defined additional benefits.
- Annual costs:
  - Average annual private sector costs; and
  - Average annual public sector costs.
- Net benefit (annual benefit minus annual cost); and
- B/C ratio (annual benefit/annual cost).

The national default and proposed performance measure impact values are shown in Table 2.5.

Monetary values assigned to the different performance measures are shown in Table 2.6.

Capabilities exist within the IDAS model to adjust these costs to current or future years. These procedures can be easily transferred to spreadsheet tools or other tools.

Table 2.5 ITS Benefit Default Values

Impact Measure	IDAS "National" Default	Proposed Value
Freeway Service Patrol		
Reduction in incident duration	55%	55%
Reduction in fatalities	10%	6%
Reduction in emissions and fuel	42%	6%
Incident Management Systems[a]		
Percent time sign is on and disseminating information	10%	2.5%
Percent vehicles that save time	20%	20%
Time savings	3 minutes	3 minutes
Dynamic Message Signs[b]		
Percent time sign is on and disseminating information	10%	1%
Percent vehicles that save time	20%	20%
Time savings	3 minutes	3 minutes
Central Corridor Traffic Signaling in High-Intensity Areas		
Capacity change on affected progression links	8%	8%
Traffic Actuated Traffic Signaling in Low-Intensity Areas	8%	8%
Capacity change on affected progression links	16%	16%
Capacity change on affected cross-flow links	-16%	-16%
Ramp Rollover Systems		
Percentage of traffic considered commercial	N/A	10%
Percentage reduction in accident rates	100%	45%
Portable Traffic Management Systems		
Percent time sign is on and disseminating information	10%	2%
Percent vehicles that save time	20%	20%
Time savings	3 minutes	3 minutes
Highway Advisory Radio		
Percent vehicles tuned into broadcast	25%	5%
Percent vehicles that save time	25%	25%
Percent time of extreme conditions	10%	2%
Time savings per traveler	4 minutes	4 minutes
Ramp Metering		
Capacity change on freeway	13.5%	13.5%
Capacity change on ramps	-50%	-50%
Accident reduction on freeway	-38%	-38%
Accident reduction on ramps	-38%	-38%

[a] This deployment is "modeled" after a Dynamic Message Sign deployment. The intent is that at either end of the affected section of roadway (or within the section), there will be notifications of some incident, and traffic will be diverted to a parallel (or associated) arterial. The effect is the same as notification via DMS.

[b] These deployments are generally in parallel with the Incident Management (IM) deployments, full impacts values here would likely "double count" those from the IM deployments.

Table 2.6 Benefit Values
(Benefits Are Reported in 1995 Dollars)

In-vehicle Value of Time per Hour	
Commercial Truck	$20.80
All Other Modes	$8.50
Travel Time Reliability Value per Person Hour	
Commercial Truck	$62.40
All Other Modes	$25.50
Cost of Fuel per Gallon	
Commercial Truck, Bus	$1.15
Autos	$1.21
Non-fuel Vehicle Operating Costs per Mile	
Commercial Truck	$0.10
Auto	$0.03
Emissions Cost per Ton – All Modes	
Hydrocarbons	$1,774.00
Nitrous Oxides	$3,731.00
Carbon Monoxide	$3,889.00
Particulates (PM_{10})	$11,066.00
Carbon Dioxide	$3.56
Accident Costs per Fatality – All Modes	
Internal Cost	$2,317,398.00
External Cost	$408,952.00
Accident Costs per Injury – All Modes	
Internal Cost	$50,760.00
External Cost	$8,958.00
Accident Cost per Property Damage-only Accident	
Internal Cost	$2,824.00
External Cost	$498.00

3.0 Case Studies

3.1 Case Study Selection Process

3.1.1 Criteria

One of the important objectives of this project is to identify ITS benefits evaluation methods that can address a wide range of needs throughout the State of Wisconsin. Historically, many in the transportation profession have viewed ITS as a solution to urban congestion and safety problems, with limited application in smaller urban and rural areas. Over time, there has been recognition of the many ITS applications that are useful in addressing transportation problems in small and medium-sized areas.

An initial categorization of geographic areas in Wisconsin developed for this project included:

- Greater Milwaukee region;
- Greater Madison region;
- Small to medium urban areas such as Green Bay, Appleton, Eau Claire;
- Rural areas; and
- Major tourist destinations such as Wisconsin Dells and Door County.

Due to the fact that the number of proposed case studies was limited and that most existing ITS applications are found in urban areas, it was not considered essential that every type of geographic area be represented. It was important, however, to make sure that there be some representation of small urban and/or non-urban areas.

Other criteria for selection of case studies addressed the characteristics of the ITS deployments themselves. These included:

- Large or complex systems involving multiple elements and technologies;
- "Stand-alone" projects designed to address a single problem or deficiency;
- Projects that address the travel needs of the general public;
- Project that address specialized markets such as commercial vehicles, public transportation or fleet management;
- Projects that represent and involve a range of users within WisDOT; and
- Case studies that use different types of data generated by WisDOT and/or local agencies.

Other evaluation criteria discussed in Task 1 addressed the characteristics of the benefits tools themselves. These criteria also influenced the selection of case studies and included:

- Applicable to a range of ITS alternatives and geographic areas;
- Input data available and of acceptable quality;
- Easy to use with limited training requirements;
- Able to incorporate results into the transportation planning process; and
- Able to transfer information forward for use in project development and design.

3.1.2 Test Procedures

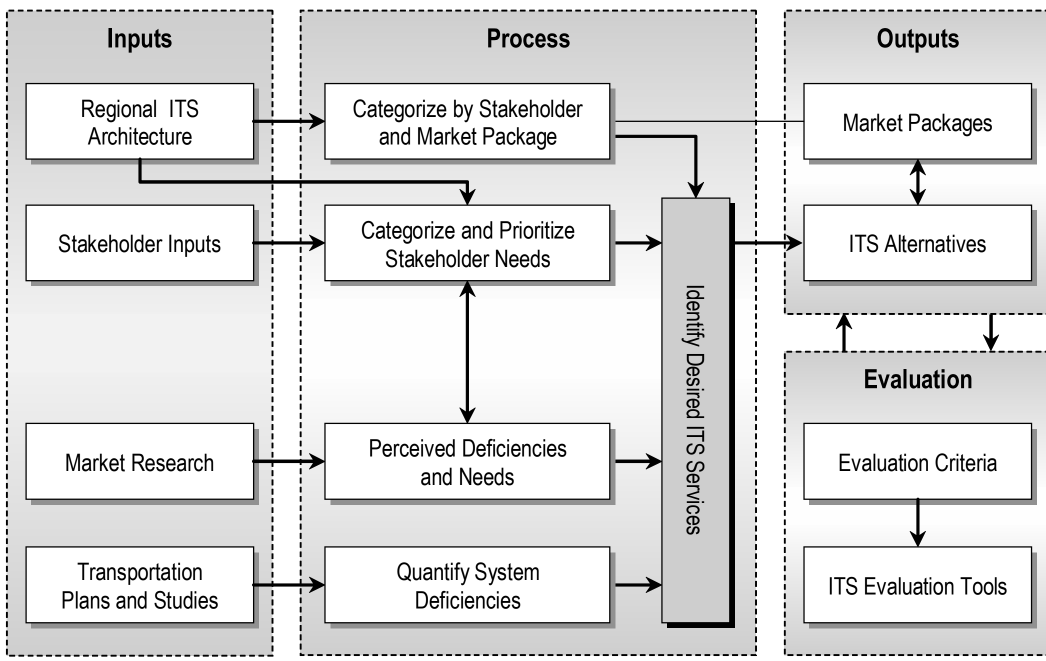
Prior to selection of case studies, a set of test procedures were developed. These procedures were needed in order to identify all of the steps necessary to test benefit/cost tools on a variety of case studies. It was also an important step in screening case studies to make sure that adequate information and supporting data were available to carry out a benefits analysis. Procedures included:

1. **Selection of Case Study Alternatives and Methods –** Case studies were identified through discussion with WisDOT personnel and other stakeholders, as well as review of existing documents such as the U.S. 41/Fox Cities ITS plan. Methods were identified through the literature search conducted as part of Task 1.
2. **Develop Case Study Description –** A brief description of each case study was developed.
3. **Identify and Obtain Measurement Data –** For each case study, a list of potential data that could be used for benefits measurement was developed. Many of these items were not available but this step helped identify what types of information would be useful.
4. **Select Parameters for Model Testing –** An initial set of parameters were identified and are documented in Section 2.0. An important objective was to identify parameters that can be collected and updated over time by WisDOT.
5. **Input Data to Models –** Data were obtained for input to the benefit/cost tools, including system costs and user data. Demand data generally consisted of either traffic counts or travel demand model estimates. Some of the proposed methods required data on network characteristics that could be obtained from either travel demand models or WisDOT metamanager data. For some of the specialized applications, other data sources were utilized.
6. **Run Models and Summarize Results –** Benefit/cost tools were applied and results summarized. Formats varied based on the tool applied.

7. **Review Results with WisDOT and Revise Parameters –** Results were submitted to WisDOT as case studies were developed. Where empirical studies of the project were available, these were used to adjust the parameters.
8. **Summarize Results –** Results are summarized in each subsection below.
9. **Transfer Models and Methodologies –** Documentation and procedures were developed for each of the tools applied. For the simpler techniques, such as spreadsheets, these tools are "self-documenting" with descriptions and input data requirements imbedded in the spreadsheet. It is important to note that the tools provided through this contract are prototypes and will go through additional modifications as they are used by WisDOT. Detailed documentation summaries are provided in the appendices to this report.

It is important to note that these tools fit within an overall planning context. The effectiveness of these tools will rely heavily on the "front-end" planning work that is used to identify problems and deficiencies in the system. As shown in Figure 3.1, these tools are most useful after problems have been identified and an initial set of solutions developed.

Figure 3.1 Process to Develop and Evaluate ITS Alternatives



This project focuses on the evaluation box in the lower right part of the figure. The evaluation tools are used to assess how well ITS alternatives meet specified criteria and provide information that can be used to refine these alternatives.

3.2 Selected Case Studies

Thirteen case studies were identified as candidates for further analysis. These case studies covered a range of technologies and applications across the State. A workshop was held in July 2002 to review the status of these projects, identify potential data needs, and review the suitability of these projects for ITS benefits analysis. Six case studies were selected for further analysis. While availability of information was the primary criterion for selection, these studies also represent a mix of geographic areas, technologies, and issues. Selected case studies are described below along with summaries of methodologies and results. In some cases, more detailed descriptions of methodology were developed; these are included in Appendices.

3.2.1 U.S. 45 Freeway Management System Milwaukee County

The U.S. 45 Freeway Management System represented an expansion of the Milwaukee region's MONITOR system to a major north-south freeway in western Milwaukee County. This project is included implementation of an integrated freeway/arterial management system along the U.S. 45 corridor between I-94 and Good Hope Road in Milwaukee County. Key elements include incident detection, surveillance, Dynamic Message Signs, and arterial signal optimization. Trailblazer signs were also installed and are used in response to incidents and construction activity to move traffic between the U.S. 45 freeway and parallel arterials STH 100 and 124th Street. The goal of this system is to minimize congestion while also minimizing the amount of time that drivers need to divert to parallel arterials. Proposed measurements and data input are shown in Table 3.1.

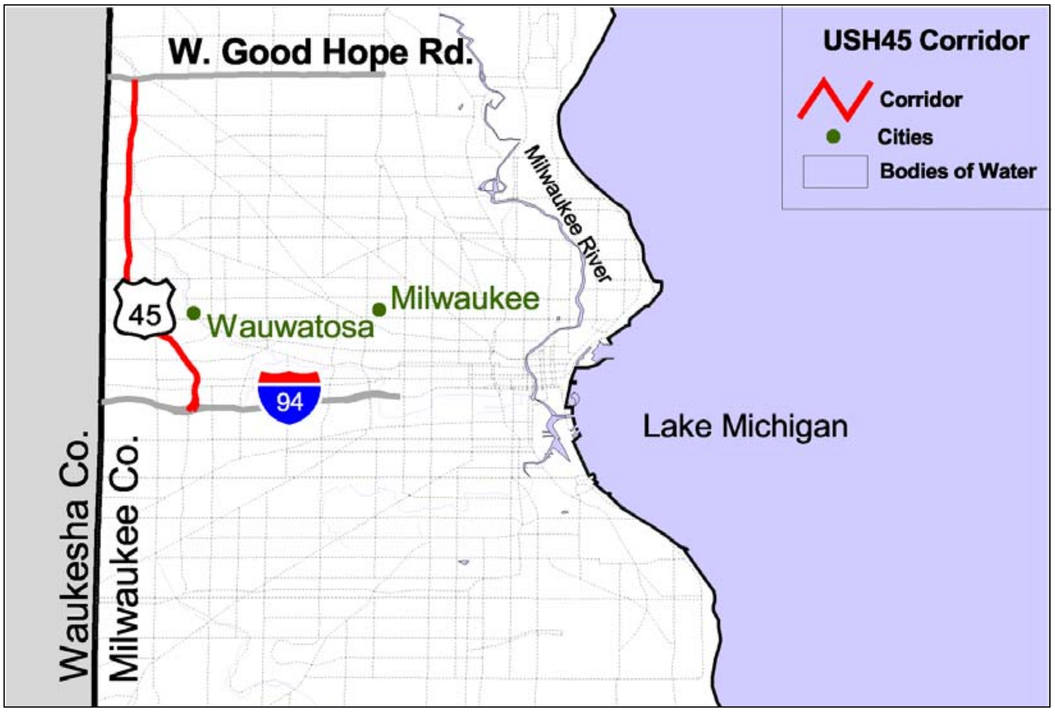
Table 3.1 U.S. 45 Freeway Management System

Performance Measures	Data
Travel Time Savings	Freeway before and after traffic volumes and speeds
	Arterial before and after traffic volumes and speeds
Accident Reduction	Freeway and arterial accident history
Vehicles Diverted	Before and after traffic volumes and speeds
Customer Satisfaction	Survey or focus groups

This project was not the subject of a before-and-after study and comparison of traffic volumes and accident rates was somewhat premature due to the fact that the system was relatively new. In addition, substantial construction activity would have influenced the results. This project was selected as case study since it was the most recent and extensive application of ITS in the Milwaukee area.

Specific elements of the system are changeable message signs, detectors, and cameras. In addition, the project included the development of a freeway-arterial coordination system utilizing "trailblazer" signs on U.S. 45 and State Route 100, a parallel arterial. The corridor is shown in Figure 3.2.

Figure 3.2 U.S. 45 Corridor
Milwaukee County



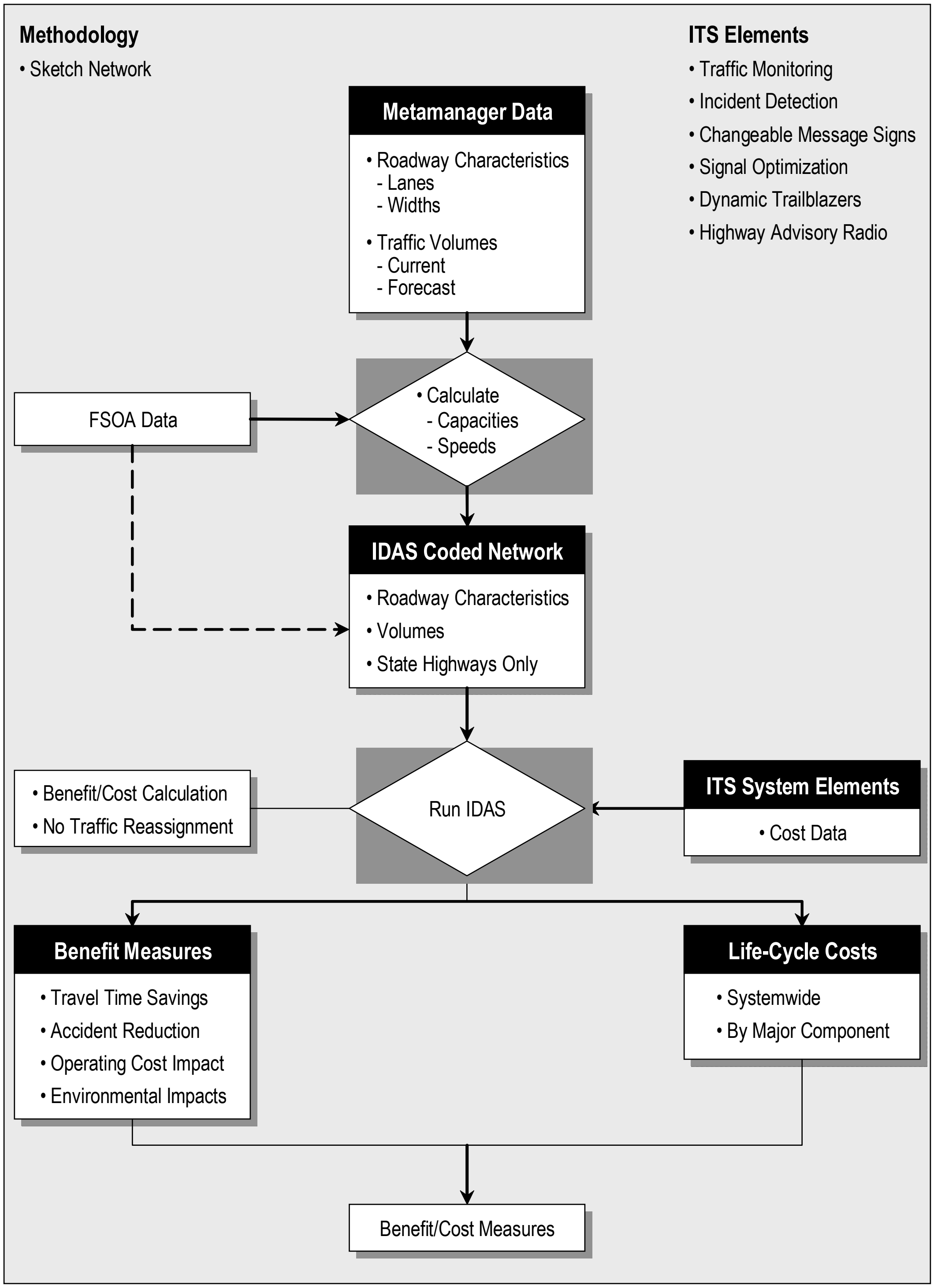
The original case study plan called for use of the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) travel demand model. However the model was not available for use in this study.

Since a regional travel demand model and IDAS are being used in two other case studies, both in the Madison area, the consultant team recommended to WisDOT that the metamanager dataset be tested in this application. The metamanager dataset includes information on roadway characteristics and traffic volumes that can be incorporated into a network model. It does not include the detailed origin-destination information found in the regional travel demand model, nor does it include county and local roads. However, origin-destination information is not always critical to the analysis of ITS benefits, particularly when evaluating short-term projects. Existing traffic volumes, or volumes projected for the short term, can be adequate for this task. Other advantages of using metamanager data are:

- The database covers the entire State and thus the benefits methodology can be applied in non-urban areas where there is no regional travel demand model available; and
- The database supports a "sketch-planning" level of analysis which is much faster to apply than one based on regional travel demand models.

Figure 3.3 shows the overall process used to develop this case study and import the data into IDAS.

Figure 3.3 Case Study 1
U.S. 45 Advanced Traffic Management System – Milwaukee County



Detailed, step-by-step procedures for conversion of metamanager data to IDAS are shown in Appendix B. Some of the limitations of the methodology are noted in the chart, including the lack of origin-destination data and the fact that traffic cannot be reassigned to reflect congestion levels. However, the method can be used to provide a quick sketch-planning evaluation in a short timeframe using available data. Also noted in the chart is the ongoing Freeway Service Operations Analysis (FSOA) project being undertaken by WisDOT District 2. In the near future, this project will provide more detailed roadway capacity calculations that can be incorporated into this methodology. The capabilities of the Paramucs microsimulation model used for FSOA, plus increasing computer power, will enable this technique to meet most of the ITS planning needs in District 2.

3.2.3 Madison Beltline Ramp Metering Project

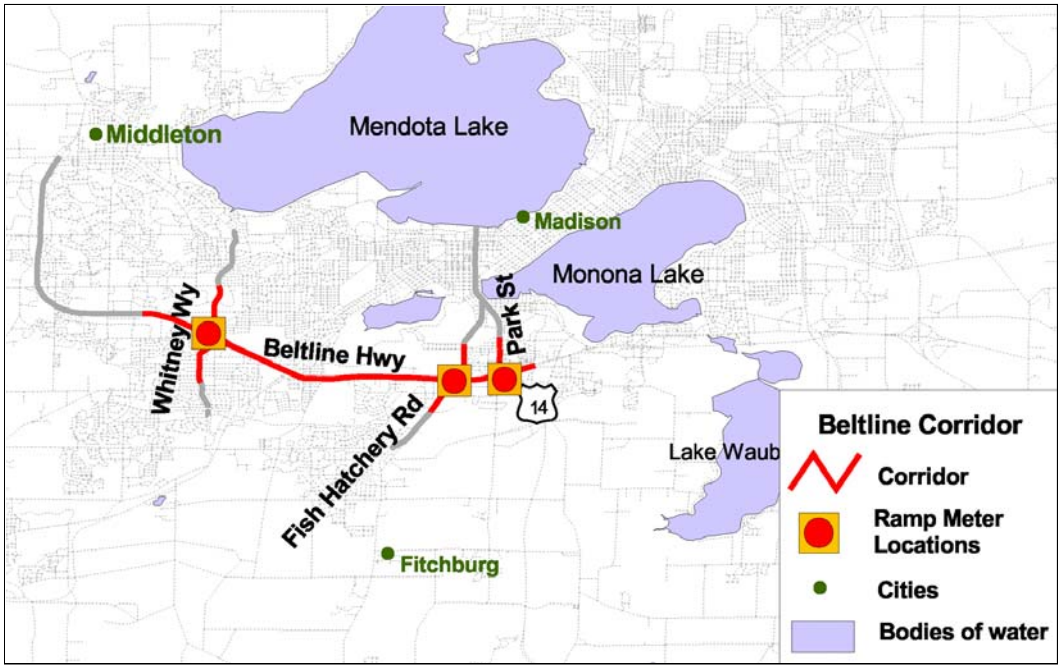
WisDOT has installed ramp meters and increased service patrols along the South Beltline Highway (U.S. 12-18) in Madison. Additional service patrols and enhanced reference markers were added as part of the project as well. Ramp meters were installed at three locations along the South Beltline in order to improve both traffic flow and safety along the highway. A map of the project is shown in Figure 3.4. Improved signal coordination to handle traffic diverted to parallel routes was also incorporated into the project. An HOV bypass at the ramp meters is provided. The University of Wisconsin was engaged by WisDOT to conduct a full evaluation, including collection of data before and after implementation. Therefore this case study provided a good opportunity to measure the benefit estimates of the proposed tools against empirical data. Proposed measurements and data input are shown in Table 3.2.

Table 3.2 Madison Beltline Ramp Meter

Performance Measures	Data
Travel Time Savings	Freeway and ramp travel speeds and times
Safety	Accident history
Travel Time Reliability	Freeway and ramp travel speeds and times
Emissions/Air Quality/Fuel Consumption	Change in VHT and VMT
Encourage HOV Use	Change in HOV usage
Motorist Acceptance	Survey or focus groups
Agency Perception	Survey or focus groups

This project provided an opportunity to use a network-based model in an urbanized setting. While the proposed program included only three ramp meters, the impacts of the metering program were likely to be felt over a wide area. The existence of empirical data through the UW study, and the timing of that study, made this case study a high-priority for the project.

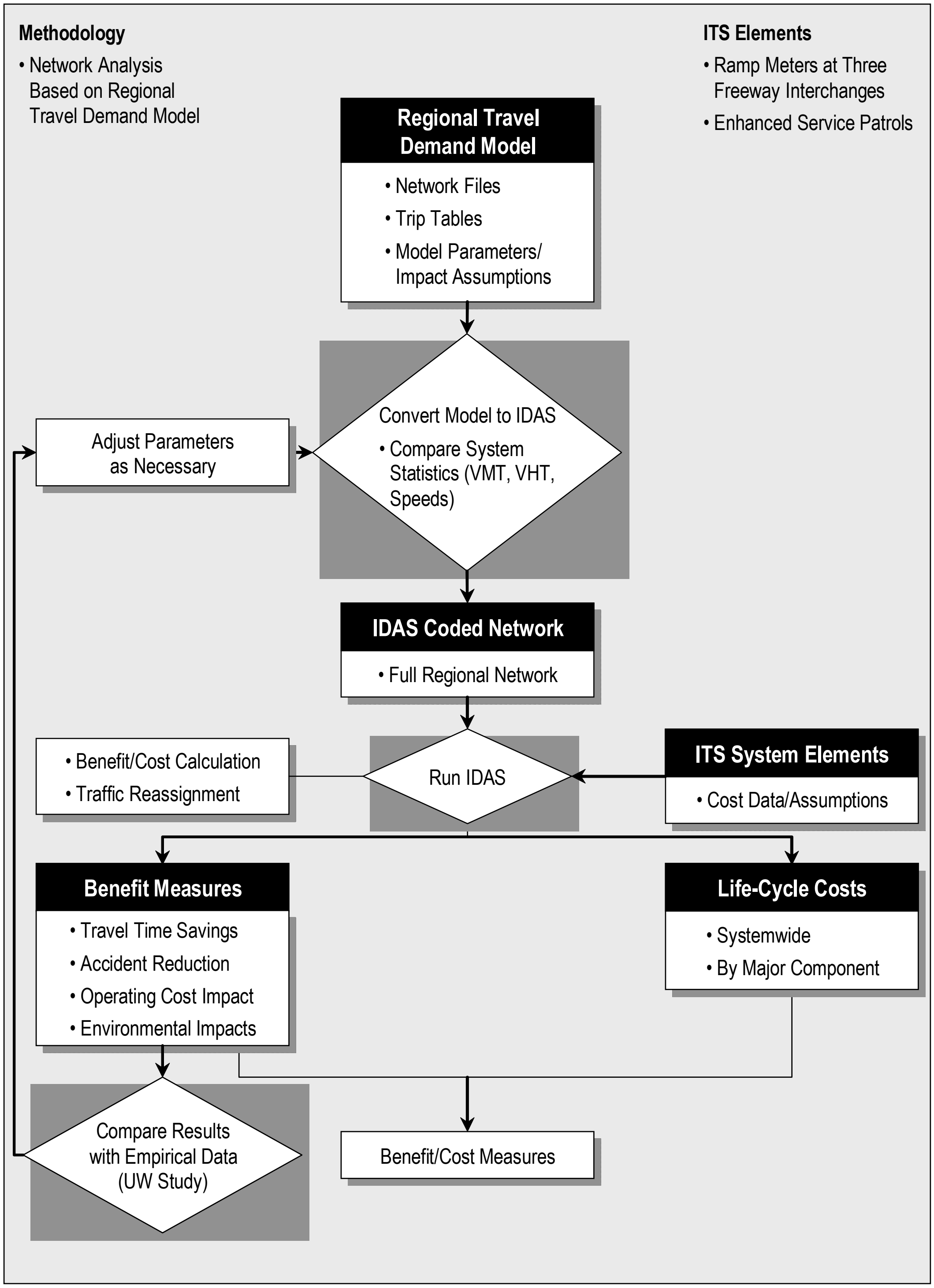
Figure 3.4 Madison South Beltline Ramp Metering Project



Network models are effective in evaluating the benefits of ramp metering, since they allow reassignment of traffic between facilities. The anticipated benefits of ramp metering include faster and safer traffic operation on metered freeway segments. However, some diversion of traffic to arterials usually occurs and waiting times required to access the freeway also offset the benefits. Both travel demand models and microsimulation models have been used to address these issues, with the ability to reassign traffic an important capability.

The Dane County regional travel demand model was converted to IDAS and an initial assessment of benefits was developed. Figure 3.5 includes a flow chart of the process used to convert the regional travel demand model into IDAS. The chart notes an important step in the process, the comparison of aggregate model estimates of vehicle-miles of travel, vehicle-hours of travel and average speeds with those produced by IDAS. This step is critical to make sure that the network has been correctly imported and that IDAS and the regional model are operating on a similar set of assumptions.

Figure 3.5 Case Study 2
Madison Beltline Ramp Metering



The results of the initial IDAS analysis were compared to an empirical study conducted by the University of Wisconsin. A comparison of the results, included in Appendix C, indicated that the assumptions in IDAS were conservative regarding the benefits obtained from ramp metering. Speed increases in the UW study were estimated at two percent in the eastbound peak direction and 10 percent in the westbound direction. IDAS estimated approximately a three percent change in both directions. Accident rate reduction was measured at approximately 50 percent in the UW study, compared to 36 percent estimated by IDAS. The major reason for these differences appears to be the geographic range of impact. The assumptions made in the initial IDAS model runs were that time savings and accident reduction benefits would be concentrated primarily on the links adjacent to the ramp meters. This appeared to be the case for accident reduction, although the actual benefits were greater than estimated in the model. Improvements in travel time were experienced along the entire corridor rather than just on the links adjacent to the meters.

Adjustments to IDAS brought estimates of speed and time savings much closer to those indicated in the UW study. In general these adjustments involved extending the benefits to additional segments of roadway along the Beltline. In addition, since most IDAS default parameters are based on studies in large urban areas, they may not be applicable in medium-sized metropolitan areas such as Madison. The availability of the UW report demonstrated how empirical data can be very helpful in adjusting parameters to reflect local conditions.

3.2.4 U.S. 41 Corridor Appleton Overheight Detection System

WisDOT identified a major problem with bridge "hits" along U.S. Route 41 between County Roads A and J in the Appleton area. Bridge hits have been a chronic problem for a number of years and potential solutions were addressed in the U.S. 41 ITS Corridor Study. The study identified a potential need for an overheight detection system, which would identify overheight vehicles and route them to the next exit using dynamic message signs. Warning alarms and sirens were also proposed to reinforce the message. Proposed measurements and data inputs are shown in Table 3.3.

Table 3.3 U.S. 41 Corridor Overheight Detection

Performance Measures	Data
System Usage	Number of vehicles warned
System Effectiveness	Number of incidents before and after
Agency Operating Costs	O&M cost data for overheight incidents
Delay	Vehicle hours of delay resulting from incident and subsequent repair activity

One of the goals of the project was to develop methodologies that are relatively easy to apply and address ITS deployments that are limited in geographic and/or technological scope. These deployments would generally involve a limited number of technologies and would cover a small geographic area. Spreadsheets appear to be the most promising application tool for these methods and would enable the tools to be disseminated to a much wider audience. While this specific project has not yet been deployed, proposals have been made and bridge repair data were available to estimate potential benefits. Therefore, this case study was selected for further analysis.

An important part of this overall effort is to supply benefit analysis tools that can be used quickly and easily to evaluate individual deployments of ITS technology. Many deployments do not require the use of a network model, and in rural areas, network models may not be available at a sufficient level of detail. In addition, a set of tools are needed for district engineering personnel who need to make quick decisions regarding deployment and do not have the staff time available to conduct detailed benefit/cost analysis. In general, spreadsheets provide the most effective tool for this purpose.

This case study used a proposal for an overheight detection system along the U.S. 41 freeway corridor near Appleton. This corridor has experienced a number of bridge "hits" from overheight vehicles, resulting in significant damage and delay to motorists. The problems in the U.S. 41 corridor result from both low bridge clearances and a large number of overheight vehicles.

The map in Figure 3.6 shows the location of the proposed overheight detection system. Overheight detectors would be placed in the northbound direction south of County Road A, and in the southbound direction north of County Road J. The technology would include radar detectors that automatically detect overheight trucks and turn on flashing beacons and changeable message signs that warn the driver to take the next exit. Additional options include audible warnings and direct links to State Patrol vehicles in the area.

Figure 3.6 U.S. 41 Overheight Detection System

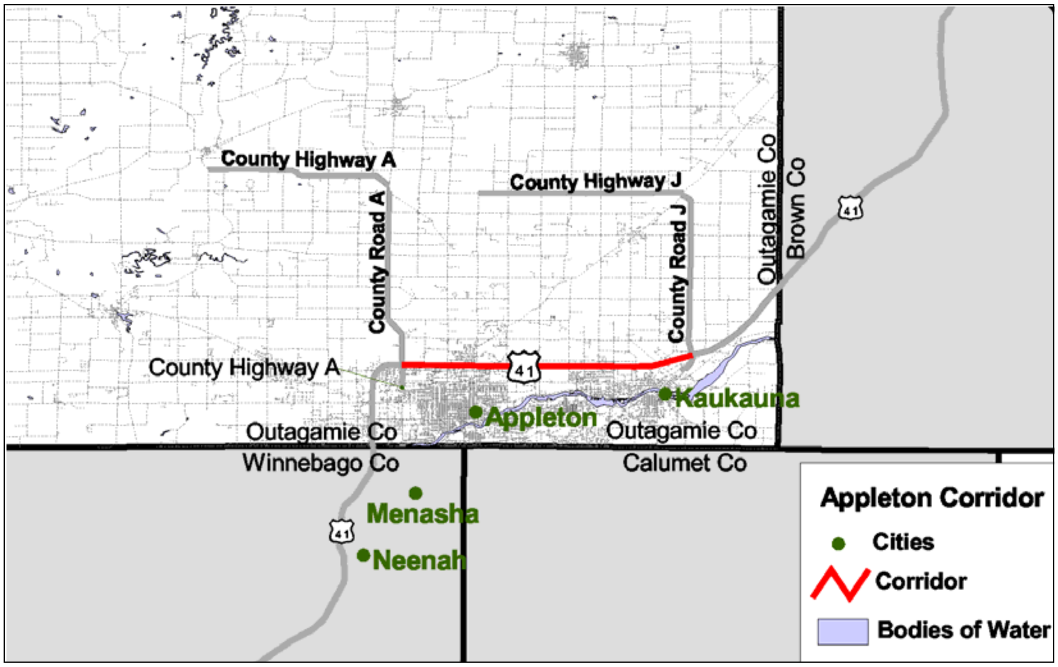
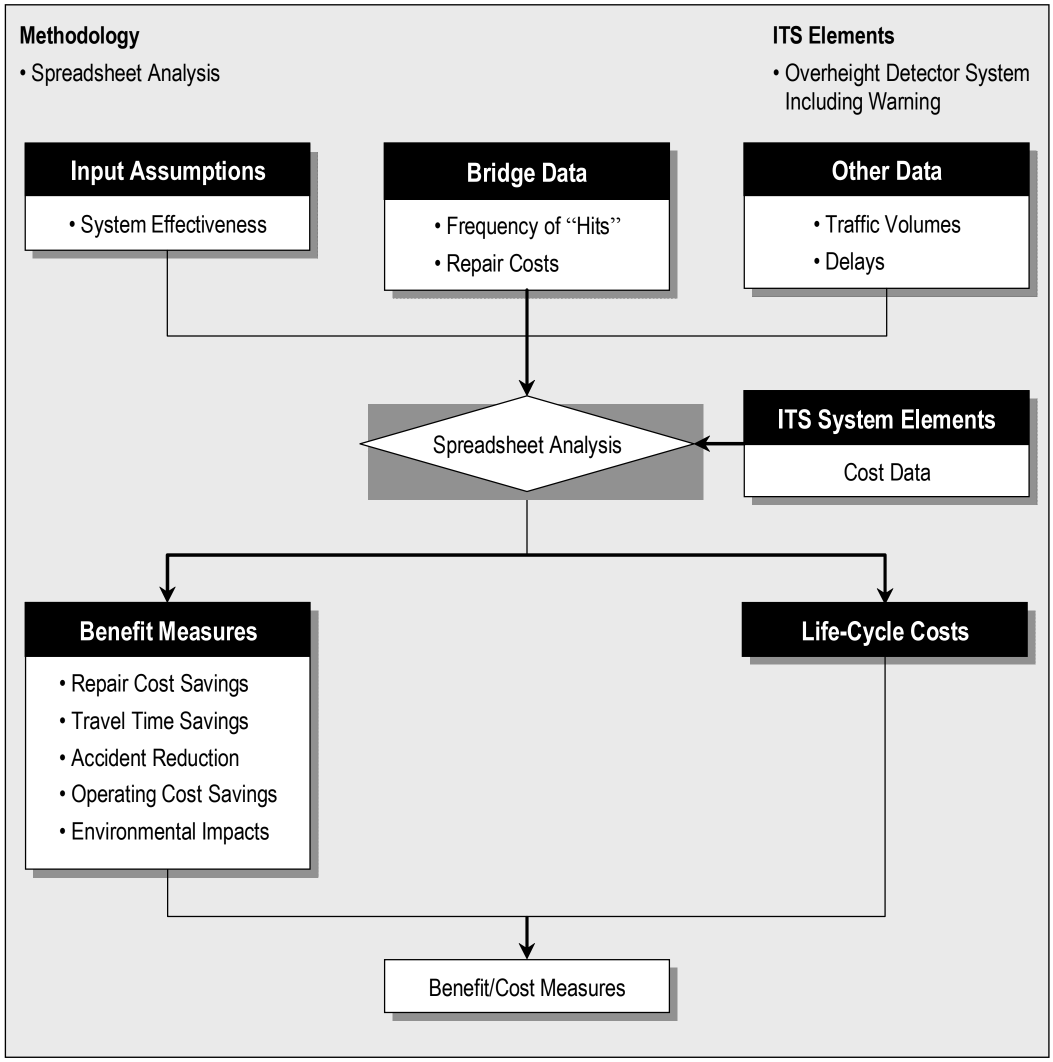


Figure 3.7 includes the process chart for the benefits analysis tool. The spreadsheet incorporated historical repair data supplied by WisDOT for the corridor. After reviewing the data, bridge hits were classified into "major" and "minor" categories. "Hit" frequency and average repair costs were calculated and incorporated into the spreadsheet. System costs were then calculated on a life-cycle basis. There is limited information at this point on the effectiveness of these systems, but it is generally perceived by transportation operators that the overwhelming majority of these hits would be avoided. The spreadsheet allows the user to test different "deterrent" rates to see where the break-even point lies.

After an initial review of the spreadsheet and methodology the technical committee asked that delay factors be incorporated into the calculation. The Madison IDAS model was used to develop a "typical" delay scenario for both the period immediately following the hit (two-thirds capacity reduction) and the subsequent construction period (one-third capacity reduction). In addition to travel times savings, reduction in delay translates into reduced crashes, reduced fuel consumption, and air quality improvement. Two WisDOT efforts currently underway, the FSOA project and a detailed study of overheight bridge hits, may ultimately provide more refined estimates of these parameters.

Appendix D includes the spreadsheet and summary of estimated benefits from the U.S. 41 corridor, as well as a sample of the benefits calculation from IDAS. Actual bridge repair costs from WisDOT's database are included as well.

Figure 3.7 Case Study 3
U.S. 41 Appleton Overheight Detection



3.2.6 Commercial Vehicle Operations Projects

A number of different ITS technologies are being applied to improve the efficiency of commercial vehicle operations. These technologies can be applied to benefit both commercial vehicle operators and the public agencies that are responsible for supervision. Two Wisconsin commercial vehicle operations projects were identified as potential case studies. One was the "smart scales" project in the I-90/I-94 corridor, which includes a variety of technologies designed to check weight, credentials, and safety history at a single location. Technologies incorporated include detection systems, weigh-in-motion, automatic vehicle classification systems, and supporting hardware, software, and communications systems. Data are currently available from one location, Hudson, on I-94 near the Minnesota border.

A second commercial vehicle operations project was also identified by the committee. This project involves the development of automated systems for advanced purchase of commercial vehicle credentials. Included are OS/OW permits, international fuel tax agreement (IFTA) payments, and international registration plans. The automated OS/OW permit system has recently been implemented for a selected number of carriers and permit services. Proposed measurements and data input for both projects are included in Table 3.4.

Table 3.4 I-90/I-94 Smart Scales Project

Performance Measures	Data
I-90/I-94 Smart Scales Project	
Improved Inspection Capability	Number of inspections
	Percent of inspections that are violators
Improved CVO Operating Efficiency	Average and total delay
Agency Operating Efficiency	Agency operating costs
Safety	Commercial vehicle accidents
	Safety violations
Automated Purchasing of Commercial Vehicle Credentials	
Agency Operating Efficiency	Agency operating costs
	Permit turnaround time
Carrier Operating Efficiency	Permit turnaround time
	Travel time savings

The committee selected these projects as case studies due to a high level of interest in commercial vehicle operations and the ability to measure the impacts of these programs. It is anticipated that the tools developed will be spreadsheet-based tools oriented toward calculation of cost savings for operators and public agencies.

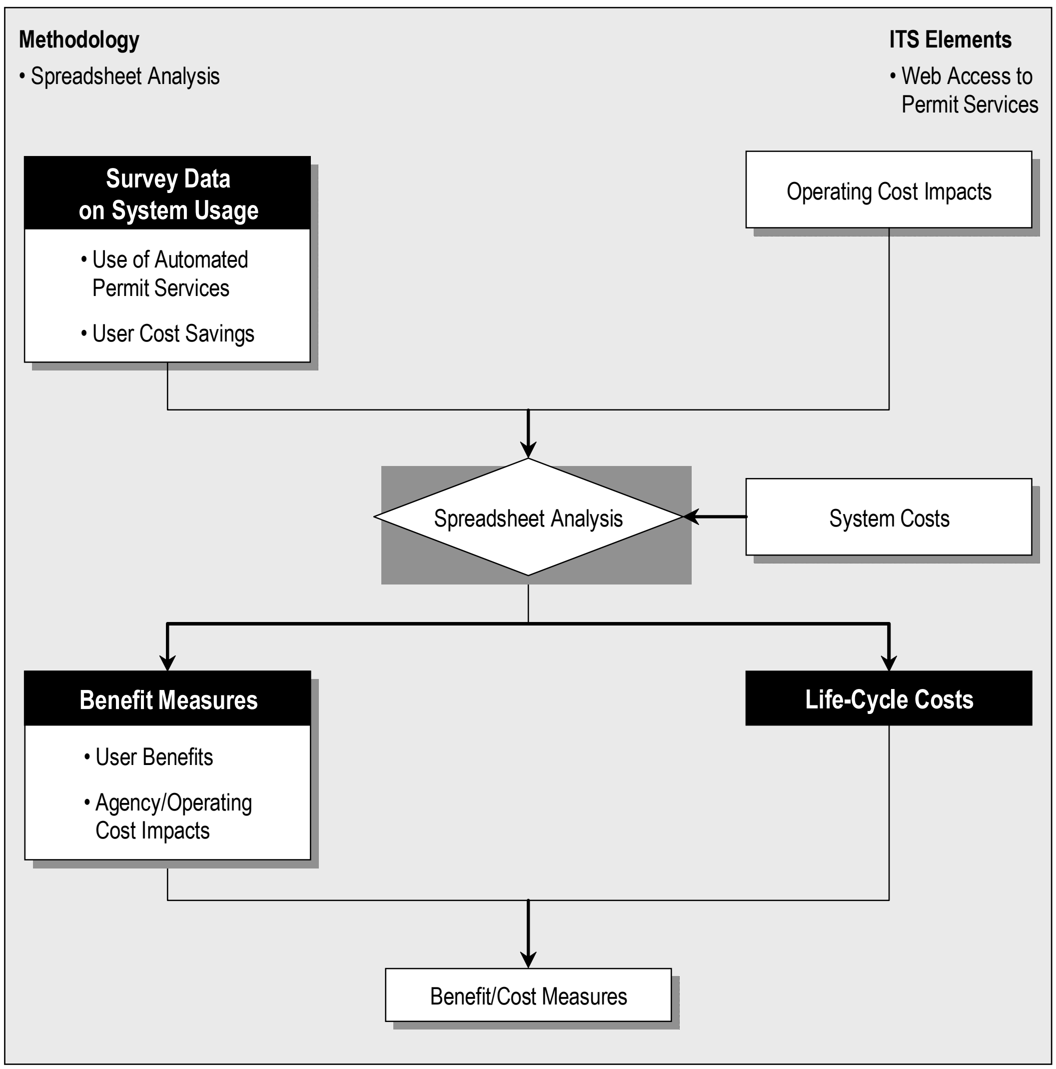
As discussed earlier, the commercial vehicle operations projects had two elements; a “smart scales” project and web-based permitting of overheight/oversize vehicles. The analysis tool for this case study will ideally be spreadsheet-based and be useful in developing other commercial vehicle-oriented projects as they are developed. At the time of this project, the amount of data available was not adequate to develop a prototype for the spreadsheet tool.

In both cases, two categories of cost savings are estimated. For the “smart scales” project, an increased number of inspections can be carried out without increasing agency operating cost. Other impacts include reduced delay for commercial vehicle operators and a reduction in the number of crashes involving commercial vehicle operators. The latter impacts can only be measured over a long period of time, however, and the implementation of this project is very recent.

Automated permitting has potentially positive financial impacts on both agency costs and operator costs. For WisDOT reduced costs are realized from a general reduction in paperwork and the ability to process applications more quickly. The automated routing system that is under development will significantly reduce the amount of labor required for permit processing.

Surveys of carriers indicate that automated permitting enables them to obtain permits more quickly and therefore reduce lead time. This leads to more efficient operation; specifically the ability to accept shipments on shorter notice and thus more fully utilize their equipment. Figure 3.8 illustrates the analysis process for commercial vehicle operations projects, using the automated permitting system as an example.

Figure 3.8 Case Study 4B
Commercial Vehicle Operations Automated Permitting



3.2.8 Global Positioning System on Fleet Vehicles

The Dane County Highway Department is sponsoring a demonstration involving deployment of Global Positioning System (GPS) technology on fleet vehicles. The key elements of the project involved the identification of a test site and outfitting of incident management vehicles with GPS. The ultimate objective is to reduce incident response times in the County by having more precise information about emergency vehicle location.

Proposed measurements and data input are shown in Table 3.5.

Table 3.5 Global Positioning System on Fleet Vehicles

Performance Measures	Data
Reduced Incident Response Time	Change in incident response time
Improved Operating Efficiency	Agency operating costs
Reduced Traffic Delays	Change in incident duration
	Change in travel speeds
Reduced Secondary Accidents	Change in accident rate/severity

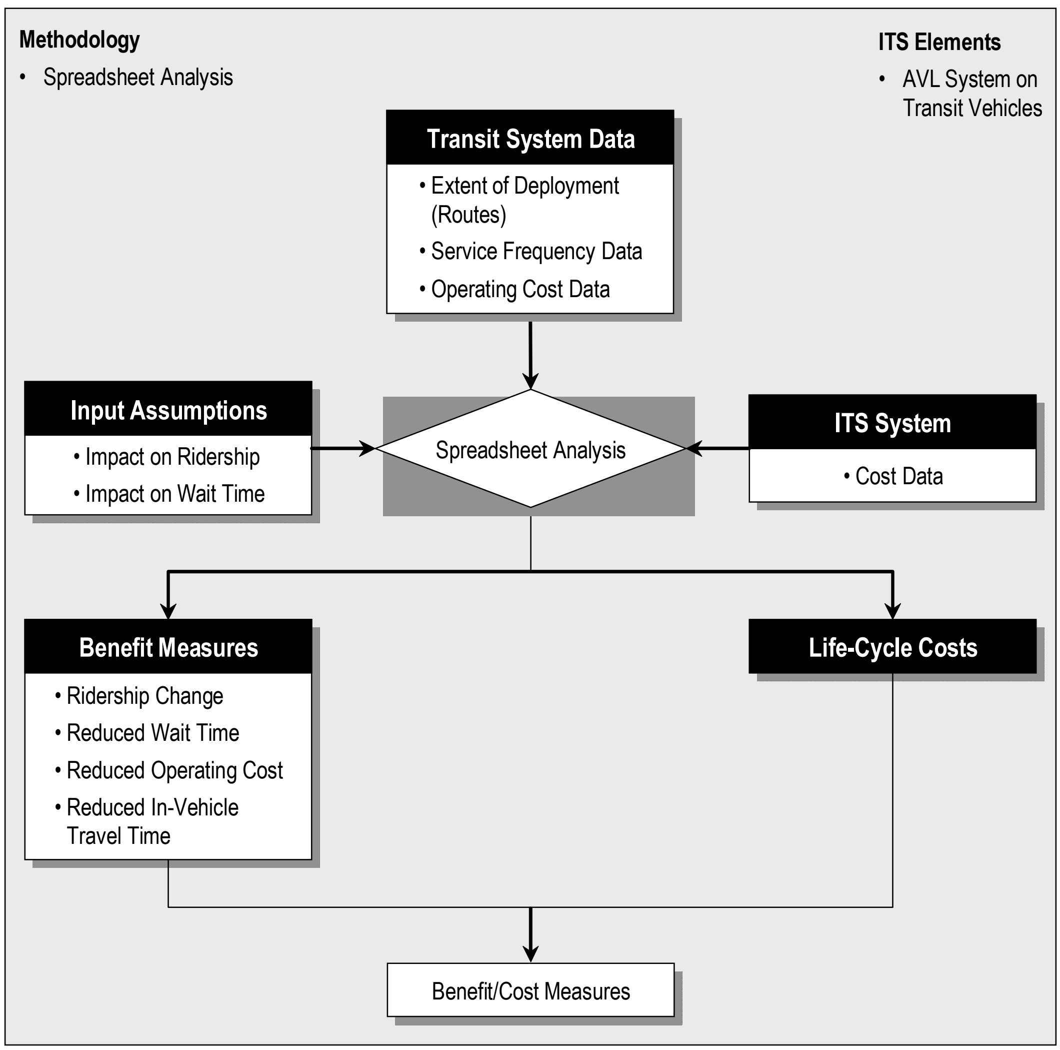
Adequate information was not available to use the Dane County fleet vehicle demonstration as a case study. However, the committee expressed an interest in a case study that could be used to assess the benefits of GPS technology, which is being widely applied in both fleet vehicles and public transit vehicles. The Milwaukee County Transit System (MCTS) has installed an Automated Vehicle Location (AVL) system using GPS on its bus fleet and has conducted evaluation work on system operational impacts. The MCTS system was selected as the case study, with development of a spreadsheet-based method that could applied to smaller transit properties and other agency fleet operators.

The original case study proposed under this category involved installation of GPS on fleet vehicles in Dane County. After initial research and discussion with the technical committee, it was agreed that installation of GPS Automated Vehicle Location (AVL) systems on public transit vehicles would provide a useful case study. Benefits gained in operating efficiency could easily be translated to fleet vehicles. Public transit offered the additional potential benefits of reduced travel time and even increased ridership.

The Milwaukee County Transit System (MCTS) has a fully installed AVL system on its bus fleet and conducted evaluation work to determine the impacts. The analysis focused primarily on agency operating cost and efficiency. The MCTS found that AVL enabled them to provide the same level of service with fewer buses. They chose not to reduce the number of buses, however, but to reduce passenger headways. Data were not available on the ridership impact of the AVL system, but as experience is gained these factors can be adjusted.

The tool developed for this case study, using the process shown in Figure 3.9, is a spreadsheet that permits the user to calculate the impacts of AVL by individual bus route, or for an entire system. A series of "user entry" cells are provided to permit sensitivity testing of different variables such as percent reduction in running time, cost savings from reduced labor and value of time saved. Methods are provided to estimate both operating costs and rider benefits. A sample spreadsheet is shown in Appendix E of this report. The sheet shows how various assumptions regarding time savings can be incorporated on a route-by-route basis.

Figure 3.9 Case Study 5
Automated Vehicle Location for Public Transportation



3.3.6 Madison East Washington Avenue Project – Construction-Oriented Traveler Information Systems

Several advanced traveler information projects were identified during the initial stages of the project. Most of the projects were located along the I-39 or the I-90/I-94 corridors and were still in the project development stage. A major construction project along I-39/I-90/I-94 was already underway and was proposed as a potential case study. Since no data were collected prior to the project, however, this did not provide WisDOT the opportunity to refine the parameters assumed in the benefits analysis tool.

The committee ultimately agreed that the East Washington Avenue reconstruction project in Madison would be a good case study for analyzing the benefits of traveler information. The project will extend over five years and involve major construction activity on the most heavily traveled approach to downtown Madison. WisDOT plans to use a variety of technologies to collect real-time information on traffic conditions, disseminate information to the public, and manage the impacts of construction. This plan outlines a five-segment construction schedule that minimizes the impact on the traveling public by focusing activity in only one segment at a time – completing all five segments in this roadway in a five-year period.

Some of the ITS elements will be movable in order to focus on the segment under construction, while others will remain permanently after they are used in the construction stage. Additionally, the plan recognizes the need for Advanced Traffic Information Systems Intelligent Transportation System (ITS) Deployments in order to inform motorists of the changing construction locations and schedule. The planned ITS deployments include five Dynamic Message Signs (DMS) at strategic locations approaching the construction sites as well as five supporting Traffic Condition Cameras (TCC) in support of the system. Finally, the plan will implement components of an incident management system to minimize incident delay and duration on the facilities in and around the construction sites.

The regional travel demand model used for the Madison South Beltline ramp metering case study was also being used as the benefits analysis tool for this case study as well. The proposed process is summarized in Figure 3.10.

This case study provided interesting results in that it recognized that the construction activity itself will inevitably result in disbenefits to the public, primarily in the form of lost travel time. IDAS, using the Madison network, provided the ability to assess the impacts of the construction activity over the five-year period if ITS were not deployed. The impacts of ITS were then evaluated, allowing a comparison of the two conditions. As shown in Table 3.6, the construction activity is estimated to result in $87 million in total disbenefits over the five-year period with $68 million resulting from lost travel time. The ITS system reduces this amount by $34 million (40 percent) to a total of $53 million with almost all of the ITS system benefits realized in improved travel time. Appendix F includes a detailed description of the analysis used to produce the summary results below.

Figure 3.10 Case Study 6
Traffic Management System for Construction Activity – East Washington Avenue/U.S. 151 Madison

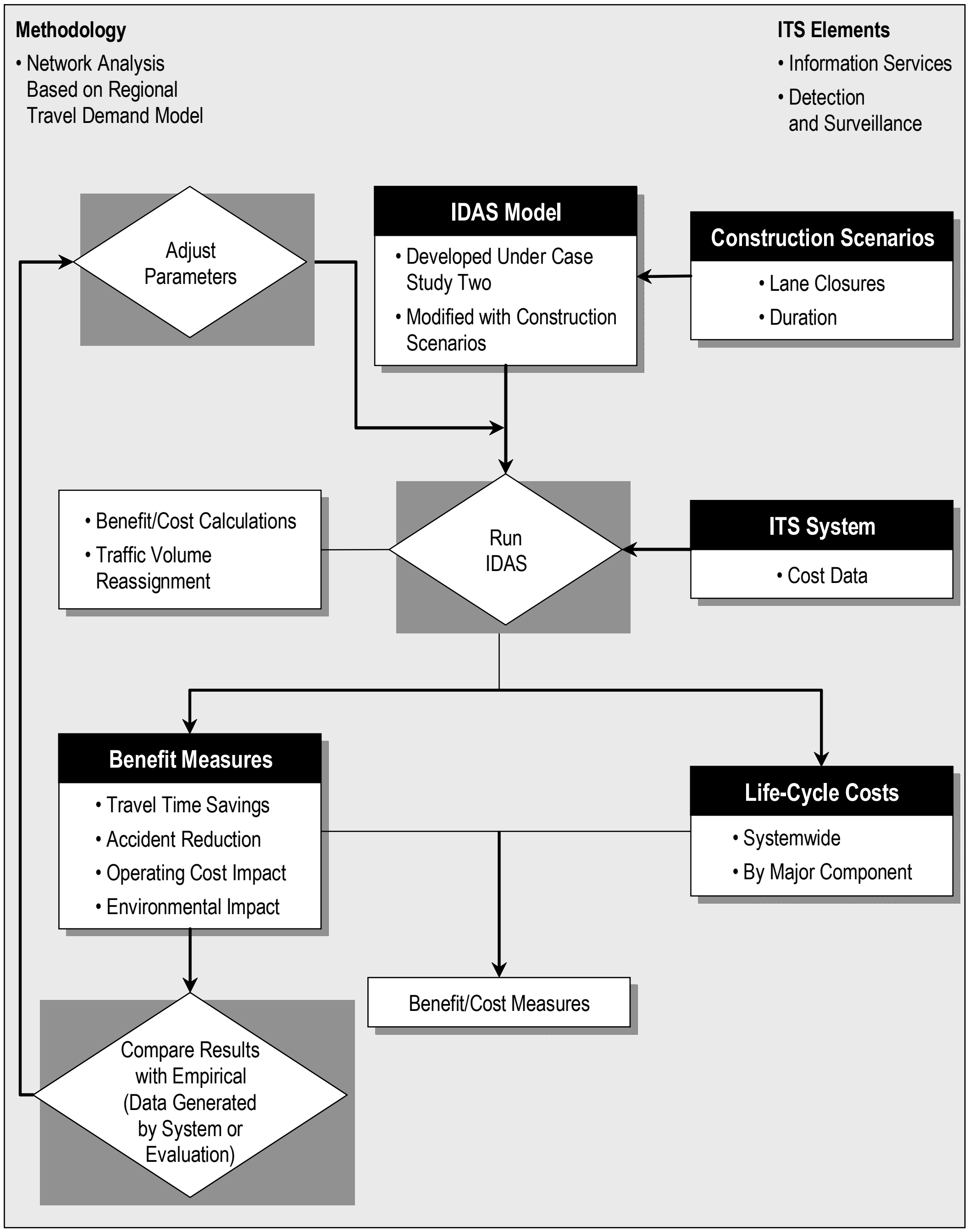


Table 3.6 Benefits Summary of East Washington ITS Project

	Construction Impact without ITS	Impact of ITS System
Benefits		
Change in User Mobility/Travel Time	-$68,000,000	$33,160,000
Fuel Costs	-$7,140,000	$460,000
Non-Fuel Operating Costs	-$1,850,000	
Accident Costs	-$4,440,000	$42,000
Emissions		
HC/ROG	-$320,000	$21,000
NO_X	-$240,000	$30,000
CO	-$5,600,000	$370,000
Other	-$20,000	
Total	**-$87,600,000**	**$34,090,000**

3.3 Summary Table

Table 3.7 includes a summary of proposed case studies, selected case studies and the concepts that will be tested during the case study development process. Additional detail on both selected and non-selected case studies can be found in the appendices to this report.

Table 3.7 Summary of Candidate Cost Studies

Number	Case Study	Selected	Concepts Tested
1	U.S. 45 Freeway Management – Milwaukee County	Yes	Sketch-planning technique using meta-manager data.
2	Layton Road Arterial Management – Milwaukee County	No	
3	South Beltline Ramp Metering – Madison	Yes	Utilize regional travel demand model data and incorporate into ITS analysis tool (IDAS).
4	U.S. 41 Overheight Detection System	Yes	Spreadsheet tool to evaluate deployment of single technology.
5	U.S. 43 Corridor Weather Information Systems	No	
6	Commercial Vehicle Operations Projects	Yes	Use field data and customer surveys to evaluate benefits to both users and WisDOT.
7	Cellular Telephone Origin Location	No	
8	Global Positioning on Public Transit Vehicles	Yes	Use transit agency operations data to develop tool for evaluation of AVL/GPS benefits.
9	I-90/I-94 Pre-Trip Traveler Information	No	
10	I-90/I-94 En-Route Traveler Information	No	Case study was changed to number 14 to test major construction project with advanced traveler information component – as well as elements of 9, 10, 11, and 13.
11	I-39 Corridor Changeable Message Signs	No	
12	I-39 Corridor Roadway Weather Information and Pavement Reporting	No	
13	I-39 Corridor Highway Advisory Radio	No	
14	East Washington Construction-Related ITS Project	Yes	Use IDAS software to test ITS deployed over five-year construction period for both construction mitigation and as part of permanent system.

4.0 Summary and Conclusions

This project involved three major tasks:

1. A literature review designed to identify state-of-the-art in ITS benefits analysis. The purpose of this task was to update previous work conducted by the University of Wisconsin-Milwaukee as well as to identify a set of benefit/cost methodologies appropriate for use in Wisconsin and a recommended a set of tools to be tested. The results of this review are documented in Task 1.0 of this report.
2. Development of a deployment philosophy for development of ITS alternatives. This philosophy is built on parameters already identified by WisDOT and covers a range of ITS solutions that can be applied in different settings across the State. This work is covered in Section 2.0 of this report.
3. Identification of candidate case studies that cover a range of ITS applications and geographic settings. Wisconsin DOT and Cambridge Systematics identified a set of potential case studies that could be used to demonstrate the ITS benefit methodologies identified during the literature search. These studies were presented to the technical committee in a workshop format and ultimately narrowed from 13 case studies to six. A summary of the candidate case studies and selection process is included in Section 3.0.

The literature search identified three levels of tools that can be applied to the evaluation of ITS benefits; network-based tools, spreadsheet-based tools and microsimulation models. All three have potential applications useful to WisDOT in assessing benefits and costs for ITS projects. The literature search indicated that these tools are progressing rapidly and already are in use in many areas. The IDAS model appears to be the most developed network-based model and has been demonstrated as part of this project. The Paramics model that has been developed for the District 2 Freeway Service Operations Analysis (FSOA) also has great utility in urbanized areas. Both models, as well as WisDOT's metamanager system, can provide data for spreadsheet applications more appropriate to smaller, stand-alone projects.

In order to evaluate ITS benefits in a structured and consistent manner, planning-level techniques are needed to develop and define alternatives for evaluation. The market packages defined as part of the ITS architecture development process provide a guideline for the development of ITS alternatives, and assure consistency of ITS planning work with the National architecture requirements. Benefit/cost analysis, however, requires development of more specific plans and proposals for ITS deployment.

This report includes a an initial set of criteria for application of ITS technologies developed by WisDOT. These criteria are similar to those used for planning physical improvements such as lane additions and intersection improvements.

At this point, these criteria provide a good starting point for determining whether ITS technologies can help to address a system problem or deficiency. As these methods are applied over time, and ITS system data are collected and analyzed, these criteria can be adjusted. Traffic volumes, projected congestion and safety are key variables in identifying and evaluating ITS systems. Proximity to the existing ITS system is another important variable that will primarily impact the cost side of the evaluation.

One of the major purposes of the benefits analysis is to identify the optimal level of investment in ITS. The level and nature of ITS investment will differ based on several variables, including traffic volumes, accident rates, economic impacts, and congestion levels. The report provides a framework for addressing these needs, based on the level of *deployment intensity***.** High-intensity deployments generally provide full coverage of a specific facility or geographic area. Low-intensity deployments can be viewed as both a way to provide ITS coverage in areas of lesser need where only limited investment is justified, and as a first step toward higher intensity deployment. Section 2.0 of the report includes the wide range of ITS technologies that have either been deployed in Wisconsin or proposed for deployment and provides guidelines as to reasonable deployment thresholds. This section also includes a summary of stakeholder priorities, as developed from a discussion guide circulated to WisDOT and other transportation agency personnel. Technologies and projects related to traveler information and incident management were generally given the highest rankings. This section also provides an initial set of benefit measures with measures falling in four general categories of travel time, accident reduction, fuel/operating cost impact and environmental impacts. An initial set of default impacts and monetary values also are provided for use by WisDOT. These measures and values should be modified over time as WisDOT develops its long-range plan and data from existing systems is studied. It is recommended that WisDOT develop standard reporting procedures for ITS systems so that impacts and performance measures can be standardized.

Six case studies were selected for analysis from total of 13 candidate projects. All but one of the projects selected had been at least partially implemented when work on the case studies began. Only two projects however, the Madison Beltline ramp metering project and the Milwaukee County Transit System AVL project, had empirical data available for comparison with benefit estimates. The work did demonstrate, however, that existing sources of data, including meta-manager and travel demand model networks can be incorporated into the IDAS software and used efficiently to develop benefit estimates. It also was demonstrated that data maintained by WisDOT and other agencies can be incorporated into relatively simple spreadsheet models. Two examples were the overheight detection case study, which used WisDOT bridge repair data, and the transit system Automated Vehicle Location case study, which used data from the Milwaukee County Transit System. Table 4.1 below includes a summary of selected case studies and the concepts tested during the case study development process. Additional detail on both selected and non-selected case studies can be found in the appendices to this report.

Table 4.1 Summary of ITS Benefits Case Studies

Number	Case Study	Concepts Tested
1	U.S. 45 Freeway Management – Milwaukee County	Sketch planning technique using metamanager data. Conversion of data was successful but metamanager data has limitations in benefits analysis due to lack of traffic assignment capability.
2	South Beltline Ramp Metering – Madison	Utilized regional travel demand model data and incorporated into ITS analysis tool (IDAS). Comparison with UW empirical study allowed adjustments to IDAS model to better reflect local conditions.
3	U.S. 41 Overheight Detection System	Developed spreadsheet tool to evaluate deployment of single technology. WisDOT bridge repair data and simulation of lane closure were used to help estimate potential system benefits.
4	Commercial Vehicle Operations Projects	Used field data and customer surveys to evaluate benefits to both users and WisDOT. Data were not adequate to develop benefits tool.
5	Global Positioning on Public Transit Vehicles	Used Milwaukee County transit agency operations data to develop tool for evaluation of AVL/GPS benefits. Tool is designed for route by route analysis but needs additional case studies to obtain data for use in smaller systems.
6	East Washington Construction-Related ITS Project	Used IDAS software to test ITS deployed over five-year construction period for both construction mitigation and as part of permanent system. Demonstrated ability to determine mitigating impacts of ITS system.

The case studies indicated that ITS benefits evaluation tools can be effectively deployed by WisDOT and also can be transferred to regional and local agencies. These tools can be used to "mainstream" ITS into the general planning process. The benefits evaluation in IDAS also can be used to evaluate other transportation projects. In order to advance the development and application of ITS benefits tools, several actions are recommended:

- Before and after studies on ITS deployments should be conducted wherever possible. The East Washington project, for example, provides a good opportunity since there are five different phases of the project. Actual measurement of ITS deployment impacts will increase the quality of estimates derived from the benefits evaluation tools.
- Training is needed to WisDOT, MPO and other local agency personnel on use of the tools. For some methods, such as IDAS, formal training is available for FHWA. For other methods less formal training may be adequate. Training also provides a means of information dissemination.
- Data should be mined from existing ITS systems, including MONITOR and the systems under development in Madison. This data stream is especially useful in tracking the performance of the system under incident conditions.

Analysis of this information not only provides improved measurement of benefits but also can help to improve actual operation of the system itself.

- The benefits analysis techniques should be incorporated into the process used to develop the STIP and the TIPs. All of the items mentioned above, particularly training, can help WisDOT accomplish this.

A. Appendix A – Case Studies

This appendix includes a brief description of the case studies that were considered but not selected for further analysis and testing. As additional data become available and additional technologies are implemented, WisDOT may consider expanding benefits analysis to these case studies in the future.

A.1 Layton Road Corridor between 20th Street and Packard Avenue, Milwaukee

The Layton Road Corridor between 20th Street and Packard Avenue in Milwaukee County is part of an Integrated Corridor Operations Program (ICOP). The project includes integration of multi-jurisdictional signals, arterial signal optimization, and changeable message signs. The Layton Road corridor project is being integrated into the MONITOR system and its operation will be coordinated with that of parallel freeways. Proposed measurements and data input are shown in Table A.1.

Table A.1 Layton Road Corridor

Performance Measures	Data
Travel Time Savings	Before and after traffic volumes and speeds
Accident Reduction	Freeway and arterial accident history
Customer Satisfaction	Survey or focus groups

The corridor project could be evaluated with either a network model or a simpler spreadsheet model. The committee indicated that some data had been collected prior to implementation but were not sure whether any after data had been collected. It will be part of the Freeway Service Operations Analysis being conducted by WisDOT District 2. The technical committee did not select the Layton Road Corridor as one of the case studies. The consensus of the Committee was that the U.S. 45 corridor was a more representative case study for major ITS deployment in the Milwaukee region and that two such studies were not necessary for this project.

A.2 Road Weather Information System Deployments on I-43 (Green Bay) and U.S. 41 (Oshkosh)

The technical committee identified Road Weather Information Systems as an area of interest, particularly in smaller urban and rural areas. RWIS have generally been used to support road maintenance activities but there is increasing interest in use of RWIS to support traveler information services. One of the ideas proposed for this project involved direct transmission of information to State Patrol officers, who would use changeable message signs to inform motorists of dangerous conditions. The proposed project also called for experimentation with different types of sensing equipment including pavement sensors and possibly subsurface probes. While the concept of operations and exact mix of technologies had not been defined, the project still provided an opportunity to assess a range of potential benefits. Proposed measurements and data input are shown in Table A.2.

Table A.2 I-43 Road Weather Information System

Performance Measures	Data
Accident Reduction	Accident history
System Usage	Traveler inquiries
State Patrol Readiness	Change in response time
State Patrol Perception	Survey or focus groups
Agency Operating Costs	Weather-related O&M costs

This case study was well-suited to application of a spreadsheet tool that could be used to assess the benefits and costs of individual RWIS installations or small systems. While the technology applications were of interest the committee did not believe that the projects were far enough advanced or that adequate data would be available to make this a viable case study. Therefore, this project was not selected for further consideration.

A.3 Cellular Telephone Origin Location and Expanded Use

This project involves increased use of cellular telephone technology to improve the ability of public safety agencies to locate emergency calls. Key elements of the project include:

- Development of test site for location of call origins;
- Testing of technologies for identifying call origins; and
- Improved management of reported calls.

The project is designed to increase the use and effectiveness of cell phones for reporting incidents. It is also hoped that the project will improve public understanding of the difference between 911 emergency calls and non-emergency calls. Technologies incorporated include wireless communications systems, and a command/dispatch center with cellular communications capability. Proposed measurements and data input are shown in Table A.3.

Table A.3 Cellular Telephone Origin Location

Performance Measures	Data
Reduced Detection Time	Number of calls Change in detection time
Improved Agency Efficiency	Agency operating costs
Reduced Response Time	Change in response time Change in incident duration
Reduced Traffic Delays	Change in travel speeds
Reduced Secondary Accidents	Change in accident rate/severity

This project has great potential for using ITS technology to improve safety and develop improved working relationships between public safety and transportation agencies. However, the committee did not feel that the project was adequately advanced to be included as a case study.

A.4 I-90/I-94 Pre-Trip Traveler Information

The I-90/I-94 ITS project included a pre-trip traveler information project that included: 1) expansion of the 1-800-ROADWIS automated telephone information service for weather information; and 2) expansion of the Internet home page. Several research projects were underway around the State to help identify best practices and set priorities for traveler information systems. Proposed measurements and data input are shown in Table A.4.

Table A.4 I-90/I-94 Pre-Trip Traveler Information

Performance Measures	Data
Level of Usage	Calls and "Internet" hits
Changes in User Behavior	Traffic volumes or customer surveys
Travel Time and Safety Benefit	Derived from consumer response
Accident Reduction	Accident rates during poor weather
Customer Satisfaction	Survey or focus groups

While there has been significant research into traveler response to information it is very difficult to establish direct links between specific traveler information services and traveler benefits. Due to the limited scope of the project and the level of uncertainty over the data collection elements, the committee did not select this project for further consideration.

A.5 I-90/I-94 En Route Traveler Information

The I-90/I-94 ITS corridor project included additional traveler information oriented toward long-distance traffic along the I-90/I94 corridor. The objective of the project was to distribute en route traffic and weather information throughout the I-90/I-94 corridor. In more congested urban areas or areas under construction, portable travel time reporting systems could be used. Free information would also be provided via cellular phones. A variety of technologies would be used including changeable message signs, highway advisory radio, cellular phones, automated interactive kiosks, real time road condition warning signs, and portable travel time reporting systems. Proposed measurements and data input are shown in Table A.5.

Table A.5 I-90/I-94 En Route Traveler Information

Performance Measures	Data
Improved Safety	Change in accident rates Change in weather-related incidents
Changes in User Behavior	Traffic volumes or customer surveys
Travel Time and Safety Benefit	Change in volumes/speeds
Customer Satisfaction	Survey or focus groups
Improved Information Dissemination	Use of service

The introduction of 511 meant that significant modifications to traveler information services would take place prior to implementation. As a result significant portions of this program were subject to change and would not be implemented in time for the study. Adequate data were not available to support the benefits analysis.

A.6 I-39 Corridor Changeable Message Signs

The I-39 ITS Corridor study proposed six changeable message signs along the corridor. The purpose of the signs was to provide information on weather, construction activity, incidents, and seasonal congestion. A major focus of the project is seasonal tourist traffic, which is often subject to delays. The signs would be operated by both WisDOT and the Wisconsin State Patrol. The project was also designed to foster cooperation between WisDOT, County, and local transportation agencies. Proposed measurements and data input are shown in Table A.6.

Table A.6 I-39 Corridor Changeable Message Signs

Performance Measures	Data
Improved Safety	Change in accident rates Change in weather-related incidents
Changes in User Behavior	Traffic volumes or customer surveys
Travel Time and Safety Benefit	Change in volumes/speeds
Customer Satisfaction	Survey or focus groups

Due to uncertainty regarding the implementation schedule, this project was not selected as one of the case studies for the project.

A.7 I-39 Corridor Additional Road Weather Information System and Pavement Reporting System

The I-39 ITS corridor study included additional RWIS installations and pavement management systems in the corridor. Key elements included four additional RWIS with remote processing stations and automated links to a Traffic Management Center, additional pavement sensors, a weather information page added to the WisDOT web site and additional information provided via CMS and HAR. Proposed measurements and data input are shown in Table A.7.

Table A.7 I-39 Road Weather Information Systems

Performance Measures	Data
Accident Reduction	Accident history
System Usage	Web site hits
System Effectiveness	Number of warnings
State Patrol Perception	Survey or focus groups
Agency Operating Costs	Weather-related O&M costs

As with the previous case study, the schedule for implementation is unclear. However, the committee was interested in testing an ITS traveler information in a rural area. They indicated that major construction projects might provide the most promising application.

A.8 I-39 Corridor Highway Advisory Radio (HAR) Project

This project called for a permanent HAR installation in the I-39 corridor just south of Merrill and two portable HAR to serve motorists approaching construction zones. The HAR system would be used to provide information on travel delays, roadway weather conditions, and construction activity. Proposed measurements and data input are shown in Table A.8.

Table A.8 I-39 Corridor Highway Advisory Radio

Performance Measures	Data
Accident Reduction	Accident history
System Usage	Customer survey or focus groups
Traffic Diversion	Traffic volumes
Safety	Construction projects

As with the previous two case studies, the schedule for implementation is unclear. However, the committee wanted to test an ITS traveler information in a rural area. They indicated that major construction projects might provide the most promising application.

B. Appendix B MetaManager Instructions

B.1 Directions for Converting MetaManager Data for Use by IDAS

Step 1. Open the .dbf File in Excel

The .dbf file contains most of the link characteristics that will be necessary for IDAS. It also contains FNODE and TNODE which are not usable (directly) in IDAS because the coordinates (X, Y) of these nodes are unknown. This problem is solved in the next step.

These are the fields present in the .dbf file:

	FNODE_	TNODE_	LENGTH	META_MANAG	META_MAN_1	PDP_ID	PDP_FRM				
(continued ->)	PDP_TO	PDP_MILE	OID_	SEG_ID	OID1	LENGTH_1	AADT	AADT_2010	TRUCK_2010		
(continued ->)	OID_1	DIVUND	NUMLANES	TRWAYWD	PTDSPEED	SFG	HCMTYPE	URBCLASS	K100_Y2010	OID1_1	INTS_NM

The fields highlighted are useful to IDAS and have the following adjustment and meaning:

Distance	=LENGTH / 5280	
Volume	=AADT_2010	
Capacity	Used to determine capacity using the following table (IDAS will not use capacity in this case, the translation table is just to have some "reasonable" data in place)	
	FRE	2000
	URB	1800
	MLT	1800
	TWO	1500
No. Lanes	=NUMLANES	
Facility Type	Used to determine facility type ID (this value will be important in determining fuel/safety/emissions rates)	
	FRE	Freeway(1)
	URB	Arterial(2)
	MLT	Arterial(3)
	TWO	Arterial(4)
Speed	=PTDSPEED	

Other fields IDAS needs for import are given the following "generated" values:

AreaType	1
Travel Mode	1
Time Speed Indicator	S
DistrictID	1

Save the resulting spreadsheet in a workbook (links.xls).

Step 2. Resolve the X, Y Coordinates of the Nodes

The MetaManager data contains a shape file (ITS0303.SHP).

A small C program was written to extract the shapes from this shape file following the ESRI standard for shape files.

As each shape is found in the shape file – distinct node numbers are created for each unique X, Y endpoint of these poly-lines and those node numbers (and coordinates) are written to a file suitable for import into Excel. Also, as each poly-line is found in the shape file – these "links" are written to an output file. These links merely contain the generated A-Node and B-Node number that was written to the node-import file. The shape file provided contains 153 distinct poly-line shapes that describe the 153 links present in the .dbf file.

Note: the fact that these 153 shapes are in the same order in the shape file as the links in the .dbf file is assumed due to the fact that this ordering is required by the ESRI shape file standard.

Open the workbook created in the prior step (links.xls) and import the nodes and links file created by the small C program into a separate sheet in that workbook ("Shape file data" in this workbook).

Add 100 to the node-numbers that will be exported. This simply makes the node numbers all greater than the "dummy" max-centroid ID number.

Note: IDAS requires the max-centroid ID be set > 0 for any database. This number is the maximum value of the centroid (zones) ID from the Travel Demand model. In our case, we are not using any trip matrixes and this number can be any value, as long as it's > 0. A value of 32 was used.

Export the node-numbers into a .prn (space delimited) file – this file will be imported into IDAS.

Note: Anytime you want to create an IDAS importable file from Excel – save your excel workbook first, then go to the worksheet containing the data, then, perform a "Save As" to the file you want to create. Ignore the warnings Excel gives about incompatible formats and save the file. Do not, however, resave the file on exit from Excel. If you do not save your workbook before exporting – any changes you would have made in that workbook will be lost.

In your links worksheet – created in step 1 and imported from the initial MetaManager .dbf file – create an A-Node and a B-Node column.

Map the A-Node and B-Node numbers in these new columns to the node-number column in the data created by the C program that read the shape file.

In this workbook, the example is as follows:

The "Shape file data" sheet contains the information read from the shape file. For links, this is in cells D-9 through E-161 and the rows are in the same order as the master link sheet. For the first link in the master link sheet, the A-node – is the value:

'Shape file data'!D9 + 100 (the 100 was not added to this data so it is added here)

For the next link, 'Shape file data'!D10 + 100

and so on.

If you simply put the formula in the first row and copy it, you can highlight that column in the remaining rows and paste – it should paste properly. Similarly, the B-node – is the *second* value from the links data, replacing 'D' with 'E' in the above formulas.

Repeat the links create so far to create the links for the "other" way.

IDAS always expects one-way links. Therefore, all the links created so far in the process must be repeated to represent the links in the other direction. Copy all links in the spreadsheet to the cells immediately below those currently in use. Then, change the A-Node and B-Node formulas such that the B-Node -> A-Node values are used – essentially swapping the A-Node and B-Node numbers.

Step 3. Create Other Columns

Create four columns in the links spreadsheet for the generated values as outlined in the first step.

Create a column that maps the HCMTYPE to facility type #. Facility type – can be any number as long as it is unique wrt facility. In IDAS, you would have defined the facility types that your import file will contain.

Create a column that maps the HCMTYPE to Capacity. Capacity will not be used in IDAS in this case. Therefore, you can simply create a column and put any number in it that you'd like.

Create a column containing distance in miles. As outlined in the first step, this column contains length (in feet) converted to miles.

Save the workbook and export the links sheet as a .prn file.

Note: The file exported will contain extraneous information starting about half-way through the file. This information is the "wrapped" columns that are of no use to IDAS and must be physically removed from the file or IDAS will have difficulty attempting to import this data.

Using any text editor, open up the exported link file and remove this data (the header information will be written in the file about halfway down – delete that and everything that follows.

Step 4. Create the IDAS Database and Import the Data

When you create a new database in IDAS, you must specify the maximum centroid ID. For this exercise, use any (small) number, The value 32 was used.

Specify the code – and color for each facility type. This exercise used a value of FT from 1-4. To do this, select File-Setup from the menu and go to the Facility Types tab. You can leave the default values just as they are or you can change the name of the first four facility types to reflect the mapping you created in the last step.

Create a new project

- Select File-New-Project from the main menu
  - Give the project a name and year of analysis (2025)

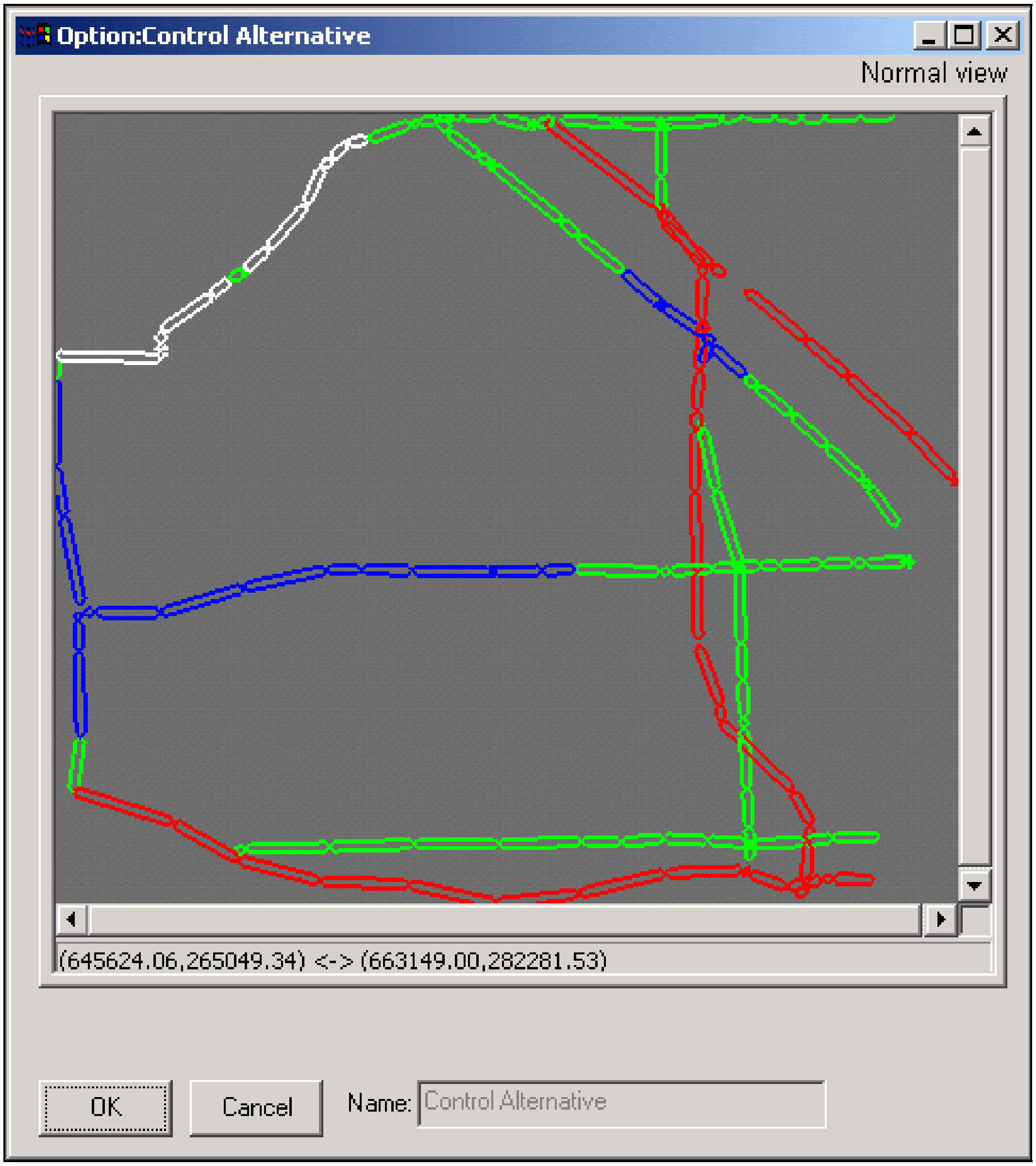
Create a new alternative

- Select File-New-Alternative from the main menu
  - Give the alternative a name
  - Use a Daily model (since the volume is in AADT)
  - Import the node file exported from your links.xls file (which should have the 100 added to each node ID)
  - Import the links file exported from the links.xls file

At this point you should have a network that you can view The data from this file produced the network to the right.

Note that there may be "missing links." This is of no importance in the current situation because our use of IDAS will not be including the "assignment" module. In other words, we are using "loaded" volumes imported into the performance data IDAS uses because we do not have travel demand matrixes that we can use with the assignment process. For this reason, the fact that our network is "invalid" in terms of having unconnected links and because we do have any centroids (or even centroid connectors), is of no real consequence.

Figure B.1 Option Control Alternative



Step 5. Activate Pass-Thru Mode

Edit the idas.ini file that is installed in the \IDAS subdirectory

- Add the key-value pair in the [IDAS] section (near the top of the file)
  - UsePassThruMode = 1

Step 6. Create the Market Sector and Import the Loaded Volumes

We still must have a market sector (even though we do not have any trip matrixes).

Create a market sector – entitled All Traffic.

Select File-New-Market Sector from the main menu.

Choose a "Multiple occupancy" travel mode.

At the bottom of the Market Sector window, there will be a button to import "loaded" volumes. Click this button and navigate to the same file used to import the links.

When you import this loaded volume, you select the following fields:

- A-Node
- B-Node
- Volume
- Speed
- TimeSpeedIndicator

Select the same fields used in the links import and click "Import."

Ignore the warning about not having imported any trip matrix when you close the Market Sector window.

Step 7. Deploy ITS Components on Your Network

You can now create a new ITS Option onto which you can deploy certain ITS Components.

Note that only a subset of the available ITS Components can be used in this limited analysis. Specifically, components that change network characteristics cannot be analyzed. This is specifically because we cannot run the assignment module (a major subsystem of the Benefits module) without a trip matrix and so cannot estimate the change in network performance due to changes in network characteristics.

However, the bulk of the ATIS (Advanced traveler information systems) deployments can be used because these deployments look at the volume on the links and calculate a benefit based on that volume. These benefits are usually provided in terms of the number of hours saved across all travelers.

Therefore, it is valid to drag-and-drop a Freeway-VMS deployment onto the network. Upon doing so, you can select the links that should be involved in the analysis and then specify the number of minutes saved by travelers due to the existence of that sign, the percent of travelers saving time, and finally, the percent of time the sign is on and disseminating information.

B.2 SHAPE FILE DATA

These links are from the shape file. They are in the same order (sequence) as in that file. The A-Node number and B-Node number are generated from the shape file – each unique x-y pair becomes a new node consecutively numbered from 1 up.

Table B.1 Sample Shape File Data

Links		Nodes		
A-Node	B-Node	Node Number	X	Y
1	2	1	649092.9	266186.8
2	3	2	649319.4	266244
3	5	3	650947.6	266279.2
5	6	4	650947.6	266279.2
6	7	5	652574.8	266342.4
7	8	6	654217.4	266341.6
8	10	7	655840	266394.6
10	11	8	656613.4	266379.2
11	13	9	656613.4	266379.2
13	14	10	657429.1	266469.3
14	16	11	658281	266417.3
16	18	12	658281	266417.3
19	20	13	659116.7	266351.1
20	21	14	660161.7	266384.5
21	23	15	660161.7	266384.5
23	24	16	660705.6	266476.8
24	26	17	660705.6	266476.8
26	28	18	661616.2	266505
28	30	19	661961.6	273285
30	32	20	661424.1	274157.3
32	33	21	661296.6	274306.7
34	35	22	661296.6	274306.7
35	37	23	660595.9	275022.5
37	39	24	659915.1	275716.1
39	41	25	659915.1	275716.1
41	43	26	659241.3	276337.7
44	45	27	659241.3	276337.7
45	47	28	659009.6	276556.5
47	49	29	659009.6	276556.5
49	51	30	658358.2	277222.7
51	53	31	658358.2	277222.7
53	55	32	658243.5	277493.5
55	57	33	658173.5	277803.7
58	59	34	658172.2	277780.9
59	61	35	658178.1	278756.2

And so on …

Table B.2 Sample Nodes

NodeNumber	X	Y
101	649092.9375	266186.8438
102	649319.375	266244
103	650947.6435	266279.1935
104	650947.6435	266279.1935
105	652574.8125	266342.375
106	654217.4375	266341.5625
107	655840	266394.5625
108	656613.3704	266379.2069
109	656613.3704	266379.2069
110	657429.125	266469.3438
111	658281.0244	266417.3293
112	658281.0244	266417.3293
113	659116.6875	266351.125
114	660161.7365	266384.5144
115	660161.7365	266384.5144
116	660705.6002	266476.7824
117	660705.6002	266476.7824
118	661616.1875	266505
119	661961.5665	273285.0292
120	661424.0625	274157.3438
121	661296.627	274306.6739
122	661296.627	274306.6739
123	660595.9375	275022.4688
124	659915.1298	275716.0754
125	659915.1298	275716.0754
126	659241.2537	276337.6506
127	659241.2537	276337.6506
128	659009.61	276556.4635
129	659009.61	276556.4635
130	658358.2103	277222.6893
131	658358.2103	277222.6893
132	658243.5	277493.5
133	658173.5	277803.6875
134	658172.1875	277780.9213
135	658178.0625	278756.2092
136	658178.0625	278756.2092
137	658177.4029	278981.4955
138	658177.4029	278981.4955
139	657414.9106	280176.4033
140	657414.9106	280176.4033
141	657307.7341	280273.8308
142	657307.7341	280273.8308

And so on …

Table B.3 Sample Links

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FNODE_	A-Node	TNODE_	B-Node	LENGTH	Distance	Speed	Volume	LaneCapacity	No. Lanes
15574	101	15566	102	239.6221171	0.045382977	45	59850	1800	4
15566	102	15560	103	1628.656254	0.308457624	45	56950	1800	3
15560	103	15550	105	1634.041916	0.309477636	45	48580	1800	3
15550	105	15551	106	1663.959568	0.315143858	45	49410	1800	3
15551	106	15538	107	1635.860959	0.309822151	45	34070	1800	2
15538	107	15541	108	774.4811674	0.146682039	45	30090	1800	2
15541	108	15528	110	821.096	0.155510606	45	31120	1800	2
15528	110	15533	111	854.2312339	0.161786219	35	21490	1800	2
15533	111	15548	113	838.7266833	0.158849751	35	29280	1800	2
15548	113	15540	114	1049.292369	0.198729615	35	22280	1800	2
15540	114	15526	116	552.0050348	0.104546408	35	23300	1800	2
15526	116	15523	118	911.243308	0.17258396	35	19870	1800	2
14764	119	14676	120	1029.23508	0.194930886	40	19050	1800	2
14676	120	14662	121	196.3399832	0.037185603	40	20780	1800	2
14662	121	14625	123	1002.02826	0.18977808	40	21290	1800	2
14625	123	14579	124	973.0882909	0.184297025	45	18970	1800	2
14579	124	14544	126	917.0611837	0.17368583	45	17710	1800	2
14544	126	14532	128	318.6501367	0.060350405	45	16910	1800	2
14532	128	14492	130	936.4358998	0.177355284	45	12650	1800	2
14492	130	14473	132	296.780757	0.056208477	45	12650	1800	2
14473	132	14455	133	318.4308822	0.060308879	55	3690	2000	3
14458	134	14406	135	975.7132749	0.184794181	55	3690	2000	3

Table B.3 Sample Links (continued)

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Facility Type	AreaType	District	TravelMode	Time/Speed	META_MANAG	META_MAN_1	PDP_ID	PDP_FRM	PDP_TO
2	1	1	1	S	3399	19662	19662	018E217 000	018E218 000
2	1	1	1	S	3400	2154	2154	018E218 000	018E219 000
2	1	1	1	S	3401	2155	2155	018E219 000	018E220 000
2	1	1	1	S	3402	2156	2156	018E220 000	018E221 000
2	1	1	1	S	3403	2157	2157	018E221 000	018E222 000
2	1	1	1	S	3404	2158	2158	018E222 000	018E222 050
2	1	1	1	S	3405	2159	2159	018E222 050	018E223A000
2	1	1	1	S	3406	2160	2160	018E223A000	018E223A052
2	1	1	1	S	3407	2161	2161	018E223A052	018E223P000
2	1	1	1	S	3408	2162	2162	018E223P000	018E225 000
2	1	1	1	S	3409	2163	2163	018E225 000	018E225 034
2	1	1	1	S	3410	2164	2164	018E225 034	018E226 000
2	1	1	1	S	8223	4861	4861	041N016R026	041N017 000
2	1	1	1	S	8224	4862	4862	041N017 000	041N017 012
2	1	1	1	S	8225	4863	4863	041N017 012	041N017F000
2	1	1	1	S	8226	19714	19714	041N017F000	041N018 000
2	1	1	1	S	8227	19050	19050	041N018 000	041N018M006
2	1	1	1	S	8228	19051	19051	041N018M006	041N018M026
3	1	1	1	S	8229	19052	19052	041N018M026	041N019 000
3	1	1	1	S	8230	18136	18136	041N019 000	041N019F000
1	1	1	1	S	8231	18137	18137	041N019F000	041N019K000
1	1	1	1	S	8232	18994	18994	041N019K000	041N019T000

Table B.3 Sample Links (continued)

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PDP_MILE	OID_	SEG_ID	OID1	LENGTH_1	AADT	AADT_2010	TRUCK_2010	OID_1	DIVUND
0.09	16027	3679	0	239.6	32110	59850	0.048	2731	D
1.02	2151	1790	1	1628.7	50180	56950	0.048	1356	D
1.01	2152	1672	2	1634	42290	48580	0.048	1270	D
1.04	2153	5325	3	1664	43050	49410	0.048	3952	D
1.02	2154	4515	4	1635.9	31770	34070	0.048	3344	D
0.5	2155	4821	5	774.5	27640	30090	0.048	3575	D
0.53	2156	6181	6	821.1	27060	31120	0.048	4570	D
0.52	2157	592	7	854.2	20664	21490	0.048	449	D
0.51	2158	1850	8	838.7	25800	29280	0.048	1399	D
0.68	2159	1762	9	1049.3	18930	22280	0.048	1333	D
0.34	2160	8332	10	552	20260	23300	0.048	6251	D
0.56	2161	7461	11	911.2	18180	19870	0.048	5478	D
0.62	4855	2468	12	1029.2	16780	19050	0.032	1849	D
0.12	4856	484	13	196.3	18310	20780	0.031	365	D
0.61	4857	3353	14	1002	18760	21290	0.031	2499	D
0.63	16069	8447	15	1008.5	16710	18970	0.032	6363	D
0.58	15594	923	16	881.7	15600	17710	0.032	680	D
0.2	15595	4143	17	318.7	14900	16910	0.032	3074	D
0.59	15596	8448	18	1233.2	8319	12650	0.033	6364	D
0.17	14977	8448	18	1233.2	8319	12650	0.033	6364	D
0.24	14978	1884	19	975.7	4269	3690	0.097	1424	D
0.56	15560	1884	19	975.7	4269	3690	0.097	1424	D

Table B.3 Sample Links (continued)

NUMLANES	TRWAYWD	PTDSPEED	SFG	HCMTYPE	URBCLASS	K100_Y2010	OID1_1	INTS_NM
4	48	45	2	URB	1	0.097	315	CTH JJ
3	38	45	2	URB	1	0.098	316	CTH Y
3	38	45	2	URB	1	0.098	317	BROOKFIELD ROAD
3	36	45	2	URB	1	0.098	318	CALHOUN ROAD
2	26	45	2	URB	1	0.101	319	MOORLAND DRIVE (NB)
2	26	45	2	URB	1	0.102	320	SUNNY SLOPE ROAD
2	26	45	2	URB	1	0.101	321	ELM GROVE ROAD
2	26	35	2	URB	2	0.105	322	N 124th STREET
2	26	35	2	URB	2	0.102	323	N 116th STREET
2	26	35	2	URB	2	0.104	324	SOUTH 100 SB
2	28	35	2	URB	2	0.104	325	
2	28	35	2	URB	2	0.106	326	
2	26	40	2	URB	2	0.106	1398	W CONGRESS STREET
2	26	40	2	URB	2	0.105	1399	CTH EE
2	26	40	2	URB	2	0.105	1400	W GRANTOSA DRIVE
2	26	45	2	URB	1	0.106	1401	CTH F
2	26	45	2	URB	1	0.107	1402	
2	26	45	2	URB	1	0.108	1403	W BOBOLINK AVENUE
2	26	45	2	MLT	0	0.113	1404	N 107th STREET
2	26	45	2	MLT	0	0.113	1405	SOUTH 175 NB MAINLINE
3	36	55	2	FRE	0	0.161	1406	SOUTH 175 NB MAINLINE
3	36	55	2	FRE	0	0.161	1407	USH 41 NB MAINLINE

And so on …

C. Appendix C

C.1 Converting the Madison, Wisconsin TDF Data for Use in IDAS

The Madison data comes from the model in a combined Nodes/Links export file produced by the model. The file has an 'N' in column 1 of the Nodes records with a blank in column 1 for each link record.

Sample Nodes Records

Node Indicator	Node Number	X Coordinate	Y Coordinate
N	1	2164632	392398
N	2	2164884	392948
N	3	2165189	392627

Sample Link Records

1	18629	8S10001000	1	1	199	0	01
1	24079	8S10001000	1	1	199	0	01
1	26489	7S10001000	1	1	199	0	01

The trip demand for the network is given in an exported "matrix" file. This file has an Origin zone (node) number, a Destination zone number, and a number of trips.

From the trip matrix file, we determine the maximum node number with in it. This tells us the number of centroids in the system.

In the current case, this number is 700.

Knowing this, we can now setup an IDAS database, set its MAX_CENTROIDID value to 700, and import the nodes just as they are given (first taking the 'N' records out of the combined file and saving them into their own file).

Next, we "expand" the links records using the following procedure:

1. The A-Node and B-Node identifiers for the link are in the first 10 columns. Separate these columns with a space so Excel can distinguish the fields. (I use an editor that can cut and paste *column-wise* which makes this very simple.)
2. The Facility type field is column 11 – put spaces around that.

3. The distance field is the next four columns. This value will be in $1/100^{th}$ of a mile so at a later step when the file we are creating gets imported into Excel – this value will be divided by 100.
4. The Time speed indicator field is next, it contains the character S. If this character contains a T, it means the "speed" column is really a Time. It is only necessary to keep the value in this column and let IDAS treat the speed column accordingly.
5. Two speed columns follow in the next eight columns. These speeds are in $1/100^{th}$ miles per hour. Therefore, during the Excel part of the conversion, these values are divided by 100.
6. Area type is in the next two columns. The next three two-digit columns are actually user assigned codes that the module user chooses to have the module export We usually make an assumption about these rows and see how the value works under that assumption after importing into IDAS.

   Naturally, the model user will always know exactly what these values are. In our case, however, we made the following assumptions:

   a. Area Type is the first value;
   b. Number of lanes is the second; and
   c. The third we use as the District column.
7. The next two-digit field is an "additional" facility type or code useful to the model. We do not use this field in the translation.
8. The next six-digit field is Capacity. We usually assume this is lane capacity for the time period duration of the model. Sometimes, however, we have to adjust this by dividing by the number of lanes field and/or multiplying by some hourly figure (if the capacities are per hour, for example).
9. The next six digits are the Volume. This figure is not strictly important on *input* to IDAS but it must be imported so that upon export, IDAS can provide its calculated value (in the column used to import the value).
10. The final digit on the links file is always a 1. This field is used by the model to indicate that the link is a one-way link. If the link were not a one-way link (this field would not have the value 1), then it would be necessary to *duplicate* this row into a new row while swapping the A-Node and B-Node fields. In such a case, it is not strictly necessary to swap any other fields (*except* capacity if that value exists in two fields) Because both Speed and Volume are calculated by IDAS.

After expanding the links file saving it to its own file, we import that file into Excel:

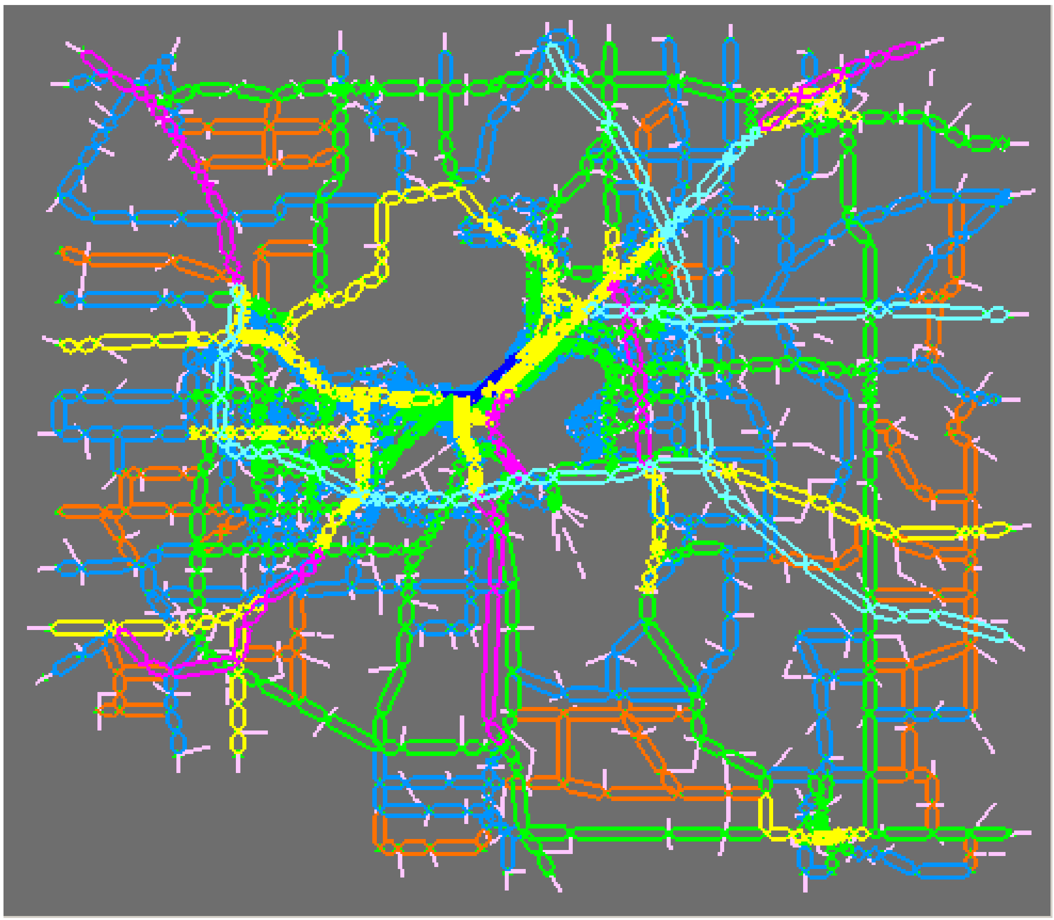
1. Add a row for header information and label the columns as outlined in the prior step.
2. Insert a column to the right of distance and set its values to the column to its left divided by 100. This column becomes the distance column imported into IDAS. After creating the formula to divide by 100, cut the column out and repaste-special choosing "values." Then, you can delete the column to its left.
3. Label the T/S indicator column. Select this entire column and center-justify the text. If you do not do this, the "S" will encroach upon the next column and will cause the IDAS import to fail.
4. Convert speed to mph. Since there are two speed columns, use the rightmost one to perform the same calculation as with distance. After cutting and paste-special the values, you can delete the first speed column.
5. Label the next three columns, Area Type, # Lanes, District.
6. You can delete the next column (a two-digit FT code), or keep it. I label it (none).
7. Label the column after that LaneCapacity.
8. And the column after that, Volume.
9. And finally, the last column, T-Mode.
10. Save the file as an excel spreadsheet.
11. Now, save the file again, except this time as a "print" file [Formatted Text (space delimited) (*.prn)]. This will create the file in a format that IDAS can import. Note, however, that you should change the name and not overwrite your.xls file.

Import into IDAS

1. If you have not already, startup IDAS and create a new database. Set the MAX Centroid ID value to 700. If we had Facility Types other than 1-9 in our links file, we would set those up in IDAS (or in a spreadsheet and import that spreadsheet in the appropriate place). Also, and importantly, we confirm that our Centroid Connector facility type corresponds to the facility type that is on the centroid connector links in our import file. In the present case, this value is 9 which is the default.
2. Create a New Project – This just requires a name and year of model data.
3. Create an Alternative – Set the time period of the run (i.e., a.m. hour) and confirm that the FT value of the centroid connector is as expected.
    a. Import Nodes – The file is just the "top half" of the original export file. When you import nodes, make sure the first column (the "N") is not assigned to a target column.

b. Import Links – Using the .prn file you exported, and the header information that should appear in the top row, select the target columns for each input column and import. You should end up with the network (in the IDAS default colors) that appears to the right.

Figure C.1 Representation of Dane County IDAS Network



Create a Market Sector

1. Once the network has been created, you can create a market sector and import the trip matrix.
2. All you have to do is select one of the transportation modes on the left side of the Market Sector window, then click File and navigate to the matrix file exported from the model.
3. You select three fields from this file, Origin-Zone, Destination-Zone, and number of Trips.
4. When you click okay, you get back to the Market sector window and then click "Import File."

IDAS is ready to run assignment.

C.2 Madison Beltline Ramp Metering Project – Comparison of IDAS Results with the University of Wisconsin Study

IDAS has been used to estimate the benefits achieved for a ramp metering project along the Beltline in Madison.

This analysis is intended to estimate the benefits that should already be realized since the ramp meters have been installed since 2001. An interesting aspect of this project is that it affords an opportunity to gauge the results of IDAS against real world observations that have already been conducted by WisDOT in and around the area of implementation.

Ramp meters have been implemented in three locations on the Beltline; On the eastbound on-ramp at Whitney Way, on two westbound on-ramps at Fish Hatcher Road, and at the Park Street westbound on ramp.

Running IDAS with this configuration produced the yearly benefits costs analysis shown in Table C.1.

The primary benefits in the above table are travel time ($1.6 million), and accident costs reduction ($1.5 million). This is due primarily to a modeled increase in volume and speed on the Beltline and to the IDAS implementation of an accident reduction impact on the Beltline links.

Table C.2 shows the IDAS modeled volumes and speeds along nine links near the affected area eastbound and the associated nine links in the westbound direction. In this data, "Improvement" means the performance of the network after the ITS deployment, and "Baseline" is the network's performance with no ramp meters deployed. It is apparent from this table that the best results of the strategy are felt in the eastern end of the implementation area.

Table C.1 Beltline Ramp Metering Benefit/Cost Summary
1995 Dollars

Annual Benefits	Weight	Alternative 1 – Ramp Meters
Change in User Mobility	0.00	–
Change In User Travel Time		
In-Vehicle Travel Time	1.00	$1,640,234
Out-of-Vehicle Travel Time	1.00	–
Travel Time Reliability	1.00	–
Change in Costs Paid by Users		
Fuel Costs	1.00	$112,375
Non-Fuel Operating Costs	1.00	$(19,928)
Accident Costs (Internal Only)	1.00	$1,250,253
Change in External Costs		
Accident Costs (External Only)	1.00	$220,630
Emissions		
HC/ROG	1.00	$7,917
NO_X	1.00	$(2,605)
CO	1.00	$179,854
PM_{10}	1.00	–
CO_2	0.00	–
SO_2	0.00	–
Global Warming	0.00	–
Noise	1.00	$(1,731)
Other Mileage-Based External Costs	1.00	–
Other Trip-Based External Costs	1.00	–
Change in Public Agencies Costs (Efficiency Induced)	1.00	–
Other Calculated Benefits	1.00	–
User-Defined Additional Benefits	1.00	–
Total Annual Benefits		**$3,387,000**

Table C.2 Volume and Speed Impacts

A-Node → B-Node		Volume Baseline	Speed Baseline	Volume with Meters	Speed with Meters	Percent Change Volume	Percent Change Speed
Westbound							
1502->1503	S. Park to FH	50032	24.6	52480	27.69	4.89%	12.56%
1503->2988	FH to exit ramp to Damon Road	51118	23.08	51803	22.11	1.34%	-4.20%
2988->1504	Damon Road exit ramp to W. BL Frontage Road (WB) entrance ramp	47892	28.09	50434	30.7	5.31%	9.29%
1504->1505	W. BL Frontage Road (WB) entrance ramp to exit ramp (for EB) to W. BL Frontage Road (EB)	53340	19.8	54379	25.06	1.95%	26.57%
1505->2976	At exit ramp (for EB) to W. BL Frontage Road (EB) to Seminole exit ramp from BL (WB)	53334	19.87	54373	18.32	1.95%	-7.80%
2976->1506	Seminole exit ramp from BL (WB) to Whenona Drive	51522	22.5	51620	22.04	0.19%	-2.04%
1506->1507	Whenona Drive to Verona Road	51522	22.43	51629	22.22	0.21%	-0.94%
1507->1508	Verona Road to S. Whitney Way	37393	32.43	37457	32.29	0.17%	-0.43%
1508->2680	S. Whitney Way to near Forward Drive	32128	45.6	32214	45.3	0.27%	-0.66%
Eastbound							
2680->1508	Near Forward Drive to S. Whitney Way	32067	45.6	32159	45.3	0.29%	-0.66%
1508->1507	S. Whitney Way to Verona Road	37196	32.84	37231	32.84	0.09%	
1507->1506	Verona Road to Whenona Drive	50470	24	51634	22.22	2.31%	
1506->2976	At Whenona Drive to Seminole entrance ramp to BL EB	50470	24	51634	28.42	2.31%	18.42%
2976->1505	At Seminole entrance ramp to BL EB to exit ramp to W. BL Frontage Road (EB)	53662	19.37	54800	24.68	2.12%	27.41%
1505->1504	At exit ramp to W. BL Frontage Road (EB) to W. BL Frontage Road (WB) entrance ramp	49347	25.71	50092	24.44	1.51%	-4.94%
1504->2988	At W. BL Frontage Road (WB) entrance ramp to W. BL Access Road (EB) entrance ramp	49347	25.88	50092	24.44	1.51%	-5.56%
2988->1503	At W. BL Access Road (EB) entrance ramp to FH	51343	22.83	51628	22.34	0.56%	-2.15%
1503->1502	FH to S. Park	49916	24.91	50231	24.44	0.63%	

A major factor in this difference will be the limited geographic range within which IDAS permits ramp metering to affect the Beltline's mainline links. It is typically recommended in IDAS ramp metering deployments to select just the one prior and one following link in the proximity of the ramp – no impacts of the ramp meter are generally expected to occur beyond this distance. However, in reality it is possible that the entire Beltline between these three ramp locations is being positively affected by the presence of the meters and indeed, this might be precisely what the differences in our results are telling us.

IDAS also estimated a lighter increase in traffic volume than did the prior study. The prior conclusions saw a 29 percent increase in volume, however, IDAS predicts around 1.5 percent increase in volume. Any volume increase in the IDAS analysis is based upon travelers attracted to the better facility (due to a capacity increase). Again, there may be characteristics of the particular routes and options available to the local traveling public that may not be captured by the IDAS model.

Interestingly, however, IDAS does predict a percent speed increase that is with 2.5 percent of the study's value for those links most affected by this deployment. This seems also to bolster the notion that the differences in the model and the observed impacts could be due to the limited scope of the deployment.

The IDAS run and the prior study agree relatively closely in accident reductions if only the links at the ramps are considered, for example, an IDAS result of 36 percent reduction can be compared to the result found of 50 percent, as shown in Table C.3. Again, any difference between these two results is likely to be due to the limited number of links within the region that is considered in the IDAS deployment. IDAS deployments for ramp metering do not generally include links further away from the deployed ramp than one link.

In light of the discrepancies between the IDAS run and the prior study, an additional IDAS run was performed with the ramp metering impact values changed from the default value of 9.5 percent capacity improvement on Beltline links to 20 percent capacity improvement.

As expected, doubling the impact values for the ramp meters roughly doubles the benefits values. The results of the second run, shown in Table C.4, show an average volume increase of three percent and a speed increase of eight percent. The bottom line benefit value increases from $3.3 million to about $7.6 million annual benefit.

Table C.3 Safety Impacts

Safety Benefits	Location	Percent Change Accidents[a]
Eastbound		
1508->2680	Near Forward Drive to S. Whitney Way	0.27%
1507->1508	S. Whitney Way to Verona Road	0.17%
1506->1507	Verona Road to Whenona Drive	0.19%
2976->1506	At Whenona Drive to Seminole entrance ramp to BL EB	0.19%
1505->2976	At Seminole entrance ramp to BL EB to exit ramp to W. BL Frontage Road (EB)	1.95%
1504->1505	At exit ramp to W. BL Frontage Road (EB) to W. BL Frontage Road (WB) entrance ramp	-36.79%
2988->1504	At W. BL Frontage Road (WB) entrance ramp to W. BL Access Road (EB) entrance ramp	-34.71%
1503->2988	At W. BL Access Road (EB) entrance ramp to FH	1.34%
1502->1503	FH to S. Park	-34.97%
Westbound		
1503->1502	S. Park to FH	0.63%
2988->1503	FH to exit ramp to Damon Road	0.56%
1504->2988	Damon Road exit ramp to W. BL Frontage Road (WB) entrance ramp	1.51%
1505->1504	W. BL Frontage Road (WB) entrance ramp to exit ramp (for EB) to W. BL Frontage Road (EB)	1.51%
2976->1505	At exit ramp (for EB) to W. BL Frontage Road (EB) to Seminole exit ramp from BL (WB)	-36.69%
1506->2976	Seminole exit ramp from BL (WB) to Whenona Drive	-36.57%
1507->1506	Whenona Drive to Verona Road	2.31%
1508->1507	Verona Road to S. Whitney Way	0.10%
2680->1508	S. Whitney Way to near Forward Drive	0.29%

[a] Percentage accident reduction will be the same for all classes of accidents because IDAS applied the same percentage to the accident rate reduction impact.

Table C.4 Network Performance Change with 20 Percent Ramp Metering Impact

A-Node → B-Node	Location	Volume	Speed	Percent Change Volume	Percent Change Speed
Eastbound					
1508->2680	Near Forward Drive to S. Whitney Way	32292	45.29801	0.51%	-0.66%
1507->1508	S. Whitney Way to Verona Road	37443	32.28814	0.14%	-0.42%
1506->1507	Verona Road to Whenona Drive	51965	21.81818	0.86%	-2.73%
2976->1506	At Whenona Drive to Seminole entrance ramp to BL EB	51965	21.6	0.86%	-4.00%
1505->2976	At Seminole entrance ramp to BL EB to exit ramp to W. BL Frontage Road (EB)	55234	17.09497	3.56%	-13.97%
1504->1505	At exit ramp to W. BL Frontage Road (EB) to W. BL Frontage Road (WB) entrance ramp	55241	30.46154	3.56%	53.85%
2988->1504	At W. BL Frontage Road (WB) entrance ramp to W. BL Access Road (EB) entrance ramp	51516	35.67567	7.57%	27.03%
1503->2988	At W. BL Access Road (EB) entrance ramp to FH	52136	21.64948	1.99%	-6.19%
1502->1503	FH to S. Park	54856	31.18111	9.64%	26.77%
Westbound					
1503->1502	S. Park to FH	50372	24.14634	0.91%	-3.05%
2988->1503	FH to exit ramp to Damon Road	51899	21.98953	1.09%	-3.66%
1504->2988	Damon Road exit ramp to W. BL Frontage Road (WB) entrance ramp	505761	24	2.49%	-7.27%
1505->1504	W. BL Frontage Road (WB) entrance ramp to exit ramp (for EB) to W. BL Frontage Road (EB)	50576	23.85542	2.49%	-7.23%
2976->1505	At exit ramp (for EB) to W. BL Frontage Road (EB) to Seminole exit ramp from BL (WB)	55647	30	3.70%	54.90%
1506->2976	Seminole exit ramp from BL (WB) to Whenona Drive	52094	34.83871	3.22%	45.16%
1507->1506	Whenona Drive to Verona Road	52094	21.62162	3.22%	-9.91%
1508->1507	Verona Road to S. Whitney Way	37328	32.5641	0.36%	-0.85%
2680->1508	S. Whitney Way to near Forward Drive	32174	45.29801	0.34%	-0.66%

D. Appendix D – Overheight Detection

An Overheight Detection System

This spreadsheet provides an analysis tool to estimate the benefits of deploying an Overheight Detection System on a facility where known impacts can be achieved by having such a system.

The deployment methodology used is derived from the IDAS (ITS Deployment Analysis System) methodology developed for the Motorist Warning class of systems. Specifically, the ramp rollover detection systems is used as the model for this deployment analysis.

The reasoning behind this approach is that the ramp rollover system is very similar to the overheight detection system in that both systems detect an unsafe condition and warn the vehicle operator of this condition. If the level of utilization of the facility by candidate vehicles (presumably commercial trucks) is known, then a measure of the benefit derived by deploying a warning system can be obtained by estimating the reduction of incidents which is, in turn, estimated as the relative "effectiveness" of the deployed equipment and the percentage of erstwhile incidents that would have been prevented because the information is presented to the operator.

Information needed to complete this analysis is:

- Number of incidents per analysis period (NORMALINCIDENTS);
- Cost incurred per incident (COSTINCIDENT); and
- Percent of operators both seeing the generated warning and heeding it (PCTEFFECTIVENESS).

The calculated benefit will be:

- NORMALINCIDENTS * PCTEFFECTIVENESS * COSTINCIDENT/100.0

or, essentially, the impact cost of reduced number of incidents.

There are no direct environmental or energy impacts for which we can provide a methodology.

However, there would be a substantial Travel Time Reliability impact that could be measured by running IDAS with a generic link deployment in the vicinity of this deployment. This is because we could provide such a deployment with a reduction in accidents and therefore allow the travel time reliability module to estimate the time savings due to the reduction of unexpected delay.

Additionally, we could obtain IDAS calculated safety benefits due to these reduction(s) in accidents.

A representative bridge hit has been analyzed using IDAS by implementing a generic ('link-based") deployment in IDAS which causes one or two lanes to be closed (in both directions) on the beltway at the intersection with Seminole.

The point of this exercise was to estimate the negative impact caused by the closure of two lanes (at the time of the accident) and then of one lane (for bridge repairs).

To use this analysis, estimate the number of days that an incident will "affect" the travel network. And insert this number in the cell under "Days incident has impact" below. Remembering that the benefits analysis provided by IDAS reflects daily impacts.

Also, estimate the number of days that a repair will take (or the number of days that one lane will need to be closed) and enter that number in the cell under "Days to repair" below.

Table D.1 System Conditions and Yearly Savings

System Conditions		**Yearly Savings (Dollars per Year)**		
Number of Big Incidents per Period	0.00260	$34,000		
Number of Small Incidents per Period	0.00315	Avoidance of Delay Caused by Incident	Days Incident Has Impact	Delay Cost per Vehicle
Cost per Big Incident ($K)	$55.80	$16,499	0.25	-$1.30
Cost per Small Incident ($K)	$2.45	Avoidance of Delay Caused by Repair	Days to Repair	Delay Cost per Vehicle
Periods per Year	247	$117,163	14	-$0.17
Predicted Impact		Yearly Capital and O&M costs		
Percent Effectiveness	90%	$20,000		
		Net Benefit (Savings–Cost)		
Daily Two-Way Volume	100,000	$147,662		
Percent of Impact	25%	Benefit/Cost Ratio (Savings/Cost)		
Reduction in Opposite Direction during Incident		8.38		
Percent of Impact	25%			
Reduction in Opposite Direction during Repair				

Cost Information

Table D.2 shows Cost Information

Table D.2 Cost Information

Estimated Cost of Deployment	$100,000
Estimated O&M Cost @ 10%	$10,000
Cost of Deployment per Year[a]	$10,000
Total	**$20,000**

[a] The equipment used in the Commercial Vehicle Ramp rollover deployment that is similar to the equipment likely to be used in an overheight deployment has a useful life of 10 years.

Benefits

Table D.3 shows a summary of the benefit/cost impacts in one day for the Beltline Ramp Metering Project (reported in 1995 dollars).

Repair Data

Table D.4 shows repair data.

Table D.3 Benefit/Cost Summary

	Weight	Alternative 1 – Bridge Hits – Two Lanes Closed	Alternative 1 – Bridge Hits – One Lane Closed
Annual Benefits			
Change in User Mobility	1.00	$(117,450)	$(15,339)
Change In User Travel Time			
In-Vehicle Travel Time	1.00	–	–
Out-of-Vehicle Travel Time	1.00	–	–
Travel Time Reliability	1.00	–	–
Change in Costs Paid by Users			
Fuel Costs	1.00	$(9,372)	$(1,174)
Non-Fuel Operating Costs	1.00	$(83)	$118
Accident Costs (Internal Only)	1.00	$3,184	$599
Change in External Costs			
Accident Costs (External Only)	1.00	$562	$106
Emissions			
HC/ROG	1.00	$(473)	$(49)
NO_X	1.00	$(231)	$(4)
CO	1.00	$(6,476)	$(787)
PM_{10}	1.00	–	–
CO_2	0.00	–	–
SO_2	0.00	–	–
Global Warming	0.00	–	–
Noise	1.00	$(26)	$1
Other Mileage-Based External Costs	1.00	–	–
Other Trip-Based External Costs	1.00	–	–
Change in Public Agencies Costs (Efficiency Induced)	1.00	–	–
Other Calculated Benefits	1.00	–	–
User-Defined Additional Benefits	1.00	–	–
Total Annual Benefits		**$(130,364)**	**$(16,531)**
Annual Costs		–	–
Average Annual Private Sector Cost		–	–
Average Annual Public Sector Cost			
Total Annual Cost		**–**	**–**
Benefit/Cost Comparison			
Net Benefit (Annual Benefit–Annual Cost)		$(130,364)	$(16,531)
B/C Ratio (Annual Benefit/Annual Cost)		–	–
Daily Vehicles	100,000		
Benefit per Vehicle		-$1.30	-$0.17

Table D.4 Repair Data

Claim ID	Date	Bridge	Cost Associated to Repair	Major	Minor
22521	2/28/1992	CTH A	$145.56		1
25419	1/10/1993	CTH A	$1,565.90		1
31133	4/7/1995	CTH A	$41,980.69	1	
36000	1/24/1997	CTH A	$38,993.01	1	
35281	4/20/1997	CTH A	$2,710.37		1
40763	7/13/1999	CTH A	$2,357.67		1
42940	4/11/2000	CTH A	$4,034.09		1
43832	8/25/2000	CTH A	$88,422.60	1	
45745	6/7/2001	CTH A	$46,122.50	1	
45747	9/10/2001	CTH A	$8,476.15		1
23880	12/23/1992	CTH CC	$86,480.94	1	
13258	10/6/1988	CTH E	$5,665.41		1
31134	7/12/1995	CTH J	$40,438.58	1	
40428	6/15/1999	CTH J	$41,368.41	1	
1747	8/24/1984	CTH J	$1,449.94		1
42781	12/8/1999	CTH J & Buchanan	$89,829.54	1	
40353	12/8/1998	Buchanan	$1,277.14		1
13315	11/2/1988	CTH N	$28,606.85	1	
40860	2/7/1999	Holland & Vandenbrook	$3,023.30		1
13558	9/7/1988	North of USH 10	$1,873.13		1
9282-3	4/4/1983	STH 125	$652.75		1
9399-3	6/3/1983	USH 10	$423.44		1
44402	12/15/2000	Vandenbrook	$609.13		1
			Number:	**9**	**14**

Major Incidents		
Earliest:	1988	
Latest:	2001	14 years
Minor Incidents		
Earliest:	1984	
Latest:	2001	18 years

Average Cost of Repairs = $23,326.40

Cost of a Big Incident (=Sum Costs 9 Incidents) = $55,804.79

Number of Big Incidents per Year (=9/14) = 0.64285714

Cost of a Small Incident (=Sum Costs/14 Incidents) = $2,447.43

Number of Small Incidents per Year (=14/18) = 0.77777778

E. Appendix E – Transit AVL

Savings Analysis

Data were collected from the Milwaukee County Transit System (MCTS) on their AVL system for the AVL/Fleet management benefits case study. A summary of the project and its impacts is provided below:

1. **Project Description –** AVL was installed on the entire MCTS fleet, including support vehicles. There is no ATSS component.
2. **Deployment Information –** The system became operational in January 1995. Implementation began in 1992. The deployment applies to the entire network.
3. **Mode Shift –** The AVL system has improved on-time performance by five to 10 percent. The AVL system has also reduced scheduled running time by five to 10 percent by allowing schedules to reflect more precisely measurable operations, but these savings have been used to increase frequency rather than reduce fleet requirements. Buses do not necessarily run faster, but slight increases in frequency may translate into slight reductions in platform waiting time.
4. **Component Usage and Cost Information –** There are 508 buses in active service. All buses have AVL. Recent bus purchases have averaged $267,000 to $270,000, including AVL installation. (AVL equipment purchased in 1995 is reused on new vehicles.) Average useful life of transit vehicles is 12 years, per FTA guidelines.
5. **Capital Cost Savings –** No reduction in peak fleet requirements due to AVL.
6. **Operating Cost Savings –** Street supervisors were reduced by seven positions (25 to 18) through attrition following AVL at an average salary of $55,000 in 2001. MCTS will provide a fringe benefits ratio. Dispatch staff was increased by approximately three full-time equivalent staff at an average annual salary of $58,000, including a new coordinator position, to accommodate the increase in call traffic. This partially offsets the elimination of the seven street supervisor positions. Given the salary levels reported, this translates into an annual salary savings of $211,000, plus fringe benefits of 63 percent or $133,000 for a total savings of $344,000.
7. **Travel Time Savings –** As above, no savings in IVTT, but five to 10 percent savings in OVTT may be appropriate. Average weekday ridership in 2000 was 232,517.
8. **Accident Data –** Accident history from 1995 through 2001 suggests an average rate of collisions of 3.82 per 100,000 vehicle miles and 2.53 passenger

accidents per 100,000 vehicle miles. These averages are slightly higher than 1990-1994 levels, but probably not because of the AVL system.

9. **Life-Cycle Costs –** Initial installation contract was $7.9 million in 1995, of which 80 percent was funded by a Federal grant.

Table E.1 Savings Analysis Summary

	Cost
Personnel Changes	
Added 3 dispatch positions	$283,620
Removed 7 street supervisors	$627,550
Savings per year	$343,930
Equipment Costs	
Capital cost = $7.9 million/10 years	$790,000
O&M	$313,000
Cost per year	$1,103,000

AVL Savings Sensitivity

Table E.2 shows the reductions in In-Vehicle Travel Time (IVTT) and Out-of-Vehicle Travel Time (OVTT) that can be expected under different scenarios. These assumptions can then be carried to the "user input" worksheet to calculate benefits to passengers and the operating agency.

User Input

User Input Sheet is shown in Table E.3.

Table E.2 AVL Transit Sensitivity

Scenario 1 = (a) Running Time Deviates +10% from Schedule (b) AVL Reduces Running Time by 5%		**Case 1 – 60-Minute Run Time**				**Case 2 – 45-Minute Run Time**				**Case 3 – 30-Minute Run Time**			
Reduction from AVL	5%												
Scheduled Running Time		60	60	60	60	45	45	45	45	30	30	30	30
Actual Running Time (+10%)	10%	66	66	66	66	49.5	49.5	49.5	49.5	33	33	33	33
Running Time with AVL		62.7	62.7	62.7	62.7	47.0	47.0	47.0	47.0	31.4	31.4	31.4	31.4
Headway		30	15	10	5	30	15	10	5	30	15	10	5
Waiting Time (50% Headway)		15	7.5	5	2.5	15	7.5	5	2.5	15	7.5	5	2.5
Extra Waiting Time		3	3	3	3	2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5
Total Waiting Time		18.0	10.5	8.0	5.5	17.3	9.8	7.3	4.8	16.5	9.0	6.5	4.0
Waiting Time Reduction		1.7	1.7	1.7	1.7	1.2	1.2	1.2	1.2	0.8	0.8	0.8	0.8
Percent Waiting Time Reduction		9%	16%	21%	30%	7%	13%	17%	26%	5%	9%	13%	21%
Access Time		7	7	7	7	7	7	7	7	7	7	7	7
Percent OVTT Reduction		7%	9%	11%	13%	5%	7%	9%	11%	4%	5%	6%	7%
Scenario 2 = (a) Running Time Deviates +15% from Schedule (b) AVL Reduces Running Time by 5%		**Case 1 – 60-Minute Run Time**				**Case 2 – 45-Minute Run Time**				**Case 3 – 30-Minute Run Time**			
Reduction from AVL	5%												
Scheduled Running Time		60	60	60	60	45	45	45	45	30	30	30	30
Actual Running Time (+15%)	15%	69	69	69	69	51.75	51.75	51.75	51.75	34.5	34.5	34.5	34.5
Running Time with AVL		65.6	65.6	65.6	65.6	49.2	49.2	49.2	49.2	32.8	32.8	32.8	32.8
Headway		30	15	10	5	30	15	10	5	30	15	10	5
Waiting Time (50% Headway)		15	7.5	5	2.5	15	7.5	5	2.5	15	7.5	5	2.5
Extra Waiting Time		4.5	4.5	4.5	4.5	3.4	3.4	3.4	3.4	2.3	2.3	2.3	2.3
Total Waiting Time		19.5	12.0	9.5	7.0	18.4	10.9	8.4	5.9	17.3	9.8	7.3	4.8
Waiting Time Reduction		1.7	1.7	1.7	1.7	1.3	1.3	1.3	1.3	0.9	0.9	0.9	0.9
Percent Waiting Time Reduction		9%	14%	18%	25%	7%	12%	15%	22%	5%	9%	12%	18%
Access Time		7	7	7	7	7	7	7	7	7	7	7	7
Percent OVTT Reduction		7%	9%	10%	12%	5%	7%	8%	10%	4%	5%	6%	7%

Table E.2 AVL Transit Sensitivity (continued)

Scenario 3 = (a) Running Time Deviates +10% from Schedule (b) AVL Reduces Running Time by 10%		Case 1 – 60-Minute Run Time				Case 2 – 45-Minute Run Time				Case 3 – 30-Minute Run Time			
Reduction from AVL	10%												
Scheduled Running Time		60	60	60	60	45	45	45	45	30	30	30	30
Actual Running Time (+10%)	10%	66	66	66	66	49.5	49.5	49.5	49.5	33	33	33	33
Running Time with AVL		59.4	59.4	59.4	59.4	44.6	44.6	44.6	44.6	29.7	29.7	29.7	29.7
Headway		30	15	10	5	30	15	10	5	30	15	10	5
Waiting Time (50% Headway)		15	7.5	5	2.5	15	7.5	5	2.5	15	7.5	5	2.5
Extra Waiting Time		3	3	3	3	2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5
Total Waiting Time		18.0	10.5	8.0	5.5	17.3	9.8	7.3	4.8	16.5	9.0	6.5	4.0
Waiting Time Reduction		3.3	3.3	3.3	3.3	2.5	2.5	2.5	2.5	1.7	1.7	1.7	1.7
Percent Waiting Time Reduction		18%	31%	41%	60%	14%	25%	34%	52%	10%	18%	25%	41%
Access Time		7	7	7	7	7	7	7	7	7	7	7	7
Percent OVTT Reduction		13%	19%	22%	26%	10%	15%	17%	21%	7%	10%	12%	15%
Scenario 4 = (a) Running Time Deviates +15% from Schedule (b) AVL Reduces Running Time by 10%		**Case 1 – 60-Minute Run Time**				**Case 2 – 45-Minute Run Time**				**Case 3 – 30-Minute Run Time**			
Reduction from AVL	10%												
Scheduled Running Time		60	60	60	60	45	45	45	45	30	30	30	30
Actual Running Time (+15%)	15%	69	69	69	69	51.75	51.75	51.75	51.75	34.5	34.5	34.5	34.5
Running Time with AVL		62.1	62.1	62.1	62.1	46.6	46.6	46.6	46.6	31.1	31.1	31.1	31.1
Headway		30	15	10	5	30	15	10	5	30	15	10	5
Waiting Time (50% Headway)		15	7.5	5	2.5	15	7.5	5	2.5	15	7.5	5	2.5
Extra Waiting Time		4.5	4.5	4.5	4.5	3.4	3.4	3.4	3.4	2.3	2.3	2.3	2.3
Total Waiting Time		19.5	12.0	9.5	7.0	18.4	10.9	8.4	5.9	17.3	9.8	7.3	4.8
Waiting Time Reduction		3.5	3.5	3.5	3.5	2.6	2.6	2.6	2.6	1.7	1.7	1.7	1.7
Percent Waiting Time Reduction		18%	29%	36%	49%	14%	24%	31%	44%	10%	18%	24%	36%
Access Time		7	7	7	7	7	7	7	7	7	7	7	7
Percent OVTT Reduction		13%	18%	21%	25%	10%	14%	17%	20%	7%	10%	12%	15%

Table E.3 User Input Sheet

	Headway/ Waiting Time		Value of Waiting Time (Dollars per Hour)	Operating Cost per hour
	2.0		$10	$50

Route	Peak Headway	Ridership	Sch. Running Time (Minutes)	Percent Extra Running Time	Percent Savings from AVL	AVL Route Time Savings(Minutes)	User Time Savings (Minutes)	Dollar Value Time Savings	Hours of Operation	Operating Cost Savings	
Main Street	30	1,000	60	10%	10%	0.6	0.3	$50.00	12.0	$6.00	
Elm Street	45	700	30	5%	10%	0.15	0.1	$8.75	10.0	$1.25	
West Avenue	15	4,000	45	10%	8%	0.36	0.2	$120.00	18.0	$5.40	
							User Benefit	$178.75		$12.65	**Agency Benefit**
						Annualized	**Factor**				
							247	$44,151.25		$3,124.55	

Note: User input cells are shown in gray. Other fields are calculated. The sheet allows calculation of benefits on a route-by-route basis.

F. Appendix F – East Washington Avenue Project – Analysis of Construction and ITS System Impacts

The Wisconsin Department of Transportation has taken a proactive step in creating a Construction Traffic Management Plan in preparation for extensive construction activity on East Washington Avenue, Madison, Wisconsin.

This plan outlines a five segment construction schedule that minimizes the impact on the traveling public by focusing activity in only one segment at a time – completing all five segments in this roadway in a five-year period.

For reference purposes, the definitions of these segments are:

- **Segment 1 –** Blair Street to Thornton Avenue;
- **Segment 2 –** Thornton Avenue to Second Street;
- **Segment 3 –** Second Street to Marquette Street;
- **Segment 4 –** Marquette Street to Melvin Court; and
- **Segment 5 –** Melvin Court to Thierer Road.

Additionally, the plan recognizes the need for Advanced Traffic Information Systems Intelligent Transportation System (ITS) Deployments in order to inform motorists of the changing construction locations and schedule. The planned ITS deployments includes five Dynamic Message Signs (DMS) at strategic locations approaching the construction sites as well as five supporting Traffic Condition Cameras (TCC) in support of the system. Finally, the plan will implement components of an incident management system to minimize incident delay and duration on the facilities in and around the construction sites.

The goal of the present study is to estimate the benefits that would be obtained due to the implementation of these ITS Strategies during the construction period. In order to perform this analysis, the IDAS system has been used to estimate the dollar benefits that should be realized due to the presence of ITS deployments.

F.1 Study Approach

A somewhat nontypical approach was used in this analysis. Understanding the way that IDAS works will help to explain this approach.

IDAS is an ITS benefits analysis tool that contains a network assignment module which estimates the performance of the network in terms of volumes and speeds. The tool also contains four subcomponents which estimate safety measures (# of accidents, etc.), fuel usage, emissions, and travel time reliability (a measure of the amount of nonrecurring delay on the network).

IDAS measures benefits due to ITS deployments on the network by applying changes to the network characteristics expected due to those deployments and then by running the assignment process against this "new" network. The changes in performance of the network over the same network with no improvements, the "Control Alternative," are parlayed into dollar valued benefits based on the value(s) of certain measures, for example, the value of time.

Given the above description of how IDAS works, we can now discuss how the approach was slightly modified in the current situation.

In this analysis, we wanted to know the benefit of having the ITS components in place *during* the construction period. However, given that construction necessarily closes a lane in one direction on some part of the network, it was recognized that the true picture would be one were the "Control Alternative," or, the network with no ITS deployments on it, was one where there were one fewer lane on the facility under construction. This is due to the fact that having the construction in place may well induce route choice decisions away from that area and without having the reduced capability of the facility in place – we would not capture the benefits over the network actually in use during the construction.

To achieve this goal, we created five separate IDAS databases – one for each segment scheduled for improvement. Then, within each of these databases, we created three different alternatives.[1] These three alternatives are:

10. **Normal Network –** The network that exists in Madison before any construction.
11. **Eastbound Construction –** A network that simply reduces by one the number of lanes on each link in the eastbound direction for that given segment. This alternative would then have a "Control Alternative" that reflects precisely the characteristics of the network at construction time.
12. **Westbound Construction –** A network changed in the same way as Eastbound construction – except one lane is reduced in the westbound direction.

Having the system broken out into five separate segments allows us to look at the benefits of having a system in place for each of the construction efforts. If the benefits for the entire project are desired, they can be obtained by simply adding the results of the separate five.

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[1] An alternative in IDAS is simply a given representation of the network. For example, if links are added or subtracted from a network, then a new alternative would be made to represent the changed network.

Another value of this approach is that it is the possible to run IDAS in such a way as to estimate the actual disbenefit of performing the construction in the first place. In other words, what level of negative impact will each segment's construction have on the traveling public. Thus providing a way to gauge each segment's impacts against each other.

One of the concerns expressed in the Traffic Management Plan is the level of route diversion into neighborhoods that is likely to occur. IDAS is able to show volume changes on alternate routes. This information can be used to predict the propensity of travelers to utilize these side streets.

F.2 ITS DEPLOYMENTS

Once the alternatives described above were built, each one could then contain an "ITS Option."[2] For each option, we deployed the following ITS Components:[3]

- DMS signs on the following locations:
  - SB Packers Avenue at International Lane (DMS-13-021),
  - WB East Washington Avenue at American Parkway (DMS-13-021),
  - WB East Washington Avenue at Parkside Drive (DMS-13-019),
  - WB East Washington Avenue at Second Street (DMS-13-020), and
  - WB South 30 at Thompson Drive (DMS-13-004); and
- Incident management systems (Detection and Response).

DMS Signs

The DMS signs used the following IDAS impact values:

- Travelers passing sign that save time – 10 percent. This value differs from the default value of 20 percent. This reduction was chosen to reflect the fact that local residents will not gain much new information after the signs are in place for a time. Even as construction information changes occasionally, local travelers will not the information and will not save additional time after a few days.
- Time the sign is turned on disseminating information – 10 percent. This is the default value in IDAS. Even though the construction will be occurring on

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[2] An ITS Option in IDAS is the deployment of one or more ITS Components onto the network defined by the alternative – the "Control Alternative."

[3] Traffic Condition Cameras were also deployed – however, these have no impact on network performance and therefore none on benefits value. Deploying these does impact the cost of the system.

a continuous basis, the same argument as in the previous bullet applies; it is not likely that local travelers will save much time except during those days when the information is fresh.[4]

- Number of minutes saved per traveler saving time – three minutes. This value is the IDAS default.

The combination of these three impact values is multiplicative. Therefore, the total time saved by travelers passing over the link where the sign is deployed =

T_s = V * 0.1 * 0.2 * 3 minutes

Where:

V is the volume on the link;

0.1 (10 percent) of the travelers save time;

0.2 (20 percent) there is the potential for saving time; and

Three minutes are saved for each traveler.

It is felt that a good assumption in the current study is that a certain percentage of the volume on these links would be nonlocal traffic. This is especially true given that this facility provides access to the State Capitol as well as to the University. Therefore, a value of 10 percent was chosen as a reasonable representation of the number of travelers that heed the signs.

Incident Management Systems

Note the Incident management system changed from segment to segment while the DMS signs are the same for every segment's analysis. This is true because the Incident Management system will be specific to each segment. However, the DMS signs are constructed once and will be in place through the duration of all of the construction – thus providing benefit to all segments in the same way.

The IM system foreseen by the traffic management plan includes the following features at a minimum:

- Utilize cameras to apprise controllers of the need to take action;
- Provide contract-towing service in the work zone; and
- Provide temporary crash investigation sites in the construction zone.

[4] Whenever IDAS benefits are considered over an annual, or appreciable length of time, it is important that the span of time be taken into account in choosing a level of effectiveness for certain ITS Deployments.

In IDAS we have used the following impact levels for the deployed IM systems:

- Incident Duration Reduction = 55 percent. This is the amount less time that is necessary to clear the facility when an incident does occur.
- Fuel consumption reduction = six percent. This is a reduction in the rate of fuel usage. This reduction is due to much fewer and shorter periods of congestion with idling and slow speeds.
- Fatality accident reduction = six percent. Fatalities are reduced because emergency personnel are able to arrive on the scene more quickly. A corresponding six percent increase will occur in the injury accident rates due to the conversion of fatalities to injuries.
- Emissions rate reduction = six percent. This measure is similar to the fuel usage reduction.

There are also default levels of expected equipment expenditures that would be necessary for implementing an IM system. However, in these runs, this equipment was set to "not installed" because it is not expected that the equipment used in this particular IM system would necessarily be the same as the equipment IDAS is expecting to implement.

F.3 THE SOCIETAL COST OF CONSTRUCTION

Before delving into an analysis of the results of ITS Deployments on these five segments, we briefly show the negative impacts on the traveling public for performing the construction in the first place. Of course, these negative results are only intended to gauge traveler inconvenience and costs because of the construction, the long-term benefit of doing the construction as well as any disbenefit associated with retaining a roadway in poor condition would clearly outweigh the negative results shown in Table F.1

F.4 THE BENEFITS OF ITS DEPLOYMENTS DURING CONSTRUCTION

The results of the IDAS analysis showed surprising consistency among the five segments. The following table shows the benefits of ITS for each of these five construction periods. Note that these values assume a one-year construction window for each segment.

We have constructed a spreadsheet where the number of days of construction for each segment can be entered by the user – this should give a more precise picture of the actual *total* benefits received over the entire construction period. On the other hand, providing the same period of construction for all segments should give a more accurate picture of how these segments compare to each other in terms of ITS performance.

Table F.1 Disbenefits of Doing Construction
Benefit Summary

Project: East Washington Avenue Construction
Benefits are reported in 1995 dollars

		With 1 Lane Closed in Each Direction (at separate times)					
Disbenefits for the Period of Construction		**Segment 1**	**Segment 2**	**Segment 3**	**Segment 4**	**Segment 5**	**Combined**
Change in User Mobility	$	(31,934,605)	(19,129,071)	(7,807,242)	(3,502,774)	(5,631,233)	(68,004,924)
Change In User Travel Time							
In-Vehicle Travel Time	$	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0
Change in Costs Paid by Users							
Fuel Costs	$	(3,542,357)	(1,876,941)	(810,237)	(423,013)	(486,224)	(7,138,772)
Non-fuel Operating Costs	$	(716,215)	(566,459)	(114,246)	(129,464)	(324,935)	(1,851,319)
Accident Costs (Internal Only)	$	(1,751,626)	(559,027)	(60,203)	(326,361)	(1,070,960)	(3,768,176)
Change in External Costs							
Accident Costs (External Only)	$	(309,106)	(98,650)	(10,623)	(57,593)	(188,992)	(664,963)
Emissions							
HC/ROG	$	(161,840)	(81,898)	(40,100)	(17,164)	(17,732)	(318,734)
NOX	$	(156,887)	(87,602)	(37,537)	(14,149)	56,485	(239,690)
CO	$	(3,048,047)	(1,655,246)	(890,071)	(247,824)	240,777	(5,600,412)
Other Mileage-Based External Costs	$	(11,644)	0	2,823	(3,457)	(6,760)	(19,039)
Total Disbenefit	**$**	**(41,632,326)**	**(24,054,894)**	**(9,767,437)**	**(4,721,799)**	**(7,429,574)**	**-87,606,029**

Segment 2 appears to obtain the best results with $7.2 million worth of benefit while segment 5 is the least recipient with a $6.3 million of benefit value. The bulk of the benefit is in the User-Mobility figure due entirely from the ATIS (DMS) deployments. This makes sense because the point of DMS is to alert travelers of time savings opportunities and we expect that there will not generally be any change in the effectiveness of these signs when the construction location changes.[5]

The fuel, accident, and emissions benefits are from the Incident Management deployments. They are the result of incidents of shorter duration and less frequency causing fewer and shorter traffic backups.

Again, there is a great deal of consistency among the five segments' results. This is most likely due to relatively equal volumes of traffic on these facilities. All of the IDAS analysis is sensitive to a Volume/Capacity speed factor curve and results will be close to the same between two facilities if volume/capacity is roughly equal between them as well.

One positive result of this consistency is that the choice of the five segments seems to have been well made in that it appears no one section is impacted substantially more than any other.

Note that IDAS produces more benefit measures than are shown in Table F.2, however, with the exception of two rows, these benefits are 0 in this analysis and are left out for clarity. The two rows shown that do contain 0s are explained next.

User Mobility and In Vehicle Time

The IDAS model contains two measures for travel time reduction benefits. These are User Mobility and reduction in In-Vehicle-Travel time. Because these are considered essentially the same benefit, only one of the results is provided by IDAS at any time. Additionally, the ATIS deployments in IDAS always result in a direct savings of time – as opposed to the In-Vehicle time reduction which is due to the *modeled* difference in time because of speed increases on certain links. To clarify further, the ATIS deployments ask for a – of expected minutes of time savings each traveler passing the ATIS equipment will experience while In-Vehicle time savings are calculated through the assignment module from higher speeds.

[5] Though, as noted before, as any one segment's construction period matures, there will likely be no new information the signs can provide. This is one reason why we took a conservative approach to the effectiveness of the signs.

Table F.2 Benefits of ITS During Construction
Benefit Summary

Project: East Washington Avenue Construction
Benefits are reported in 1995 dollars

		With Construction Period ITS Deployments					
Benefits for the Period of Construction		**Segment 1**	**Segment 2**	**Segment 3**	**Segment 4**	**Segment 5**	**Combined**
Change in User Mobility	$	6,583,210	7,234,376	6,387,032	6,632,170	6,325,782	33,162,571
Change In User Travel Time							
In-Vehicle Travel Time	$	0	0	0	0	0	0
Out-of-Vehicle Travel Time	$	0	0	0	0	0	0
Travel Time Reliability	$	0	0	0	0	0	0
Change in Costs Paid by Users							
Fuel Costs	$	132,810	97,207	85,402	63,435	78,678	457,533
Non-fuel Operating Costs	$	0	0	0	0	0	0
Accident Costs (Internal Only)	$	7,031	6,354	7,831	7,483	7,903	36,603
Change in External Costs							
Accident Costs (External Only)	$	1,241	1,121	1,382	1,321	1,395	6,459
Emissions							
HC/ROG	$	8,159	4,548	3,754	2,330	3,081	21,872
NOX	$	6,820	5,477	6,201	5,576	6,187	30,261
CO	$	136,518	82,565	64,697	37,787	52,898	374,466
Total Benefits	**$**	**6,875,790**	**7,431,649**	**6,556,299**	**6,750,102**	**6,475,924**	**34,089,764**

Travel Time Reliability

Travel Time Reliability is a measure of a more predictable travel environment. The TTR methodology has been developed by FHWA for freeway facilities only. For this reason, the TTR module is not used in the benefits analysis of the five segments shown in Table F.3. However, since Incident Management systems are especially favorable to TTR results, we have allowed IDAS to use the TTR routine for the East Washington Avenue facility to get comparative numbers, with the caveat that the reader should understand the TTR model is designed for freeway facilities and certain leeway must be considered for these results.

Additionally, because the TTR module requires two or more lanes to correctly analyze the amount of incident delay, and because segments 1 and 2 each have only two lanes per direction, it is not possible to run TTR analysis on those segments. Since the segments have two lanes, closing one leaves too few lanes for the TTR module to work. Therefore, we are only able to show TTR results, again with the above caveat, for segments 3, 4, and 5. This does not imply that Incident Management is not important on segments 1 and 2. Indeed, with only one open lane during construction – an incident would have a more severe impact on the throughput on the facility.

F.5 THE FUTURE BENEFITS OF ITS DEPLOYMENTS

All of the benefits described above have been given in terms of the impacts construction will have on the system. However, it seems logical that the future of the Madison network is likely to be improved if the ITS Systems were deployed in a more permanent way such that they would be available after construction has ended.

To help understand whether such a strategy would be economically viable, we have made an IDAS run which includes all of the ITS Deployments previously discussed and which uses the normal (no construction) Madison network as the Control Alternative.

If all of the DMS were kept in place and the Incident Management system were in use over the entire span of East Washington Avenue, then the annual benefits to such a system are shown in Table F.4. Note that we have not included specific costs within this analysis so it should be remembered that these benefits would be weighed against the capital and O&M costs necessary. As a point of reference, the IDAS costs for these deployments (DMS, CCTV, and IM components) amounts to about $1.4 million per year. This cost does not include any Traffic Management Center facility though it does include those parts of that facility that would be necessary to support these deployments (video wall, labor, etc.).

Table F.3 Estimates of Travel Time Reliability During Construction
Benefit Summary

Project: East Washington Avenue Construction
Benefits are reported in 1995 dollars

		Travel Time Reliability on Segments with 3 or More Lanes			
TTR Benefits for the Period of Construction		**Segment 3**	**Segment 4**	**Segment 5**	**Combined**
Change In User Travel Time					
Travel Time Reliability	$	1,799,915	1,838,823	1,762,666	5,401,404
Total Benefit	**$**	**1,799,915**	**1,838,823**	**1,762,666**	**5,401,404**

Table F.4 Future Annual Benefit in Retaining ITS
Annualized Benefit/Cost Summary

Project: East Washington Ave. Construction
Benefits are reported in 1995 dollars

	Entire Network
Annual Benefits	**ITS**
Change in User Mobility	$3,680,025
Change In User Travel Time	
In-Vehicle Travel Time	0
Out-of-Vehicle Travel Time	0
Travel Time Reliability	0
Change in Costs Paid by Users	
Fuel Costs	$526,011
Non-fuel Operating Costs	0
Accident Costs (Internal Only)	$61,127
Change in External Costs	
Accident Costs (External Only)	$10,787
Emissions	
HC/ROG	$20,054
NO_x	$45,638
CO	$336,620
Total Annual Benefits	**$4,680,263**

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